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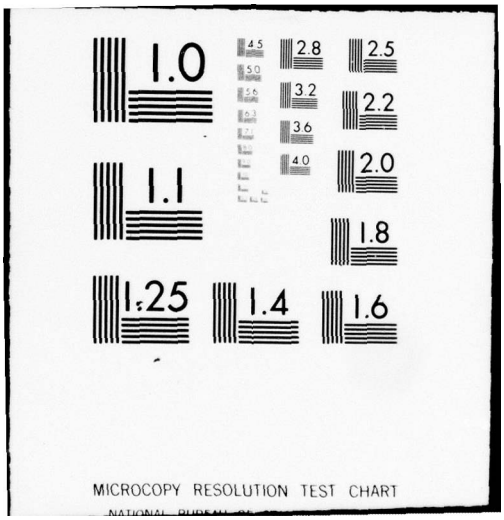
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LEVEL II

Research and Development Technical Report

DELET-TR-78-2958-2

LOW NOISE EBS JAMMER

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John B. Rettig
WATKINS-JOHNSON COMPANY
3333 Hillview Avenue
Palo Alto, CA 94304

June 1979

Second Triannual Report for Period 1 Dec 1978 - 31 Mar 1979

Prepared for:
ELECTRONICS TECHNOLOGY & DEVICES LABORATORY

ERADCOM
US ARMY ELECTRONICS RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

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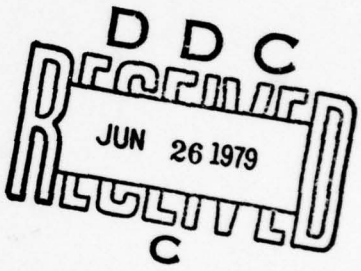
LOW NOISE EBS JAMMER

SECOND TRIANNUAL REPORT

1 DECEMBER 1978 THROUGH 31 MARCH 1979

Contract No. DAAB 07-78-C-2958

File No. WJ-78-4172TR2



Prepared by:

Douglas B. Clark
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For

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(18) (19) **REPORT DOCUMENTATION PAGE**

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: DELET-TR-78-2958-2	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER: (9)	
4. TITLE (and Subtitle): (6) Low Noise EBS Jammer.	5. TYPE OF REPORT & PERIOD COVERED: Second Triannual rept. no. 2, 1 Dec 1978 to 31 Mar 1979
(14) WJ-22-4142R2	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Douglas B. Clark and John B. Rettig	8. CONTRACT OR GRANT NUMBER(s): (15) DAABØ7-78-C-2958
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Watkins-Johnson Company, 3333 Hillview Avenue, Palo Alto, CA 94304 371 100	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Electronics R&D Command, Fort Monmouth, New Jersey 07703, DELET-BS	12. REPORT DATE: May 1979
	13. NUMBER OF PAGES: Unclassified
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): (11) Jun 79	15. SECURITY CLASS. (of this report): (12) 63p.
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electron Beam Semiconductor
EBS Amplifier
Electron Gun
Diode

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this program is to reduce the output power level of spurious noise signals, intermodulation (IM) products and harmonic distortion generated by deflection modulated electron beam semiconductor (EBS) amplifiers. Work performed during this period included characterization of existing EBS amplifiers, computer aided electron gun analysis, beam shape analysis of operating electron guns, and design modifications to the existing electron guns.

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FOREWORD

Identification of Engineering Personnel

Douglas B. Clark, Project Engineer

John B. Rettig, Member of Technical Staff

Descriptive Background of Key Personnel

Biographical sketches for each of the key personnel are included in the Appendix.

Publication, Lectures, Reports and Conferences

1.	Publications	None
2.	Lectures	None
3.	Reports	Monthly Status Reports December 1978 through March 1979
4.	Conferences	Progress on subject contract. Watkins-Johnson Company personnel and Mr. Robert M. True of ERADCOM, Fort Monmouth, N.J. Held at Watkins-Johnson Company on 20-22 March 1979.

Program for the Next Internal

The Program Plan shown in Figure 2-2 and described in Section 6.0 represents our best estimate of work to be carried out during the next reporting period.

TABLE OF CONTENTS

ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Objective

The program objective is to reduce the output power level of spurious noise signals, intermodulation (IM) products and harmonic distortion generated by deflection modulated electron beam semiconductor (EBS) amplifiers.

1.2 Technical Approach

Figure 1-1 illustrates the configuration of a deflected beam EBS amplifier. This type of amplifier has been developed by Watkins-Johnson Company over a period of several years. Measurements of existing EBS amplifiers will be made to determine the typical values of IM products, spurious noise and harmonic distortion. The existing electron beam profile will be characterized using a slit beam analyzer. The EBS performance will be correlated to the measured beam profile using a mathematical analysis implemented by a computer program. A second computer program will perform an analysis of the expected beam profile generated by the existing gun geometry and these results will be correlated with the measured beam profile. Modifications will then be performed on the electron gun to improve the linearity, IM products and harmonic distortion; and the re-designed gun will be fabricated and tested on the beam analyzer. Two devices using the re-designed gun will be fabricated, tested and delivered as part of this contract.

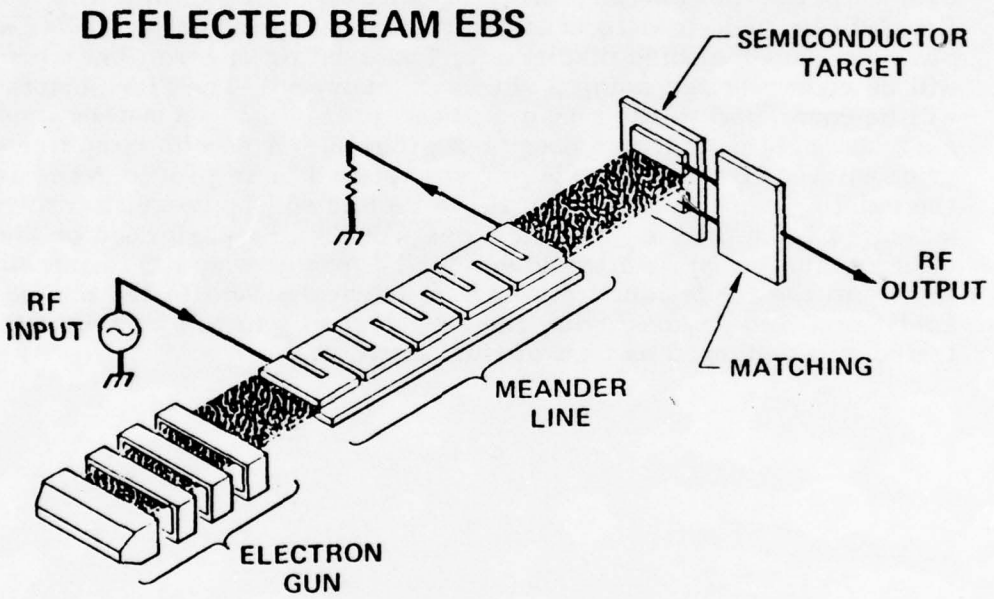

Figure 1-1. Deflected Beam EBS Configuration

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2.0 PROGRAM SUMMARY

2.1 Summary of Work

During the four month period covered by this report, the following was accomplished:

1. The existing EBS amplifiers having 2 × 6 diode arrays were completely characterized in terms of linearity and intermodulation products as a function of device efficiency.

2. The computer aided analysis of the present gun performance was completed. Several conclusions were drawn from the results, and areas of potential improvements were identified.

3. Work continued on methods of analyzing actual shape of electron beams. Calibration of an existing slit diode array was not satisfactory, so a fabrication of a new slit diode array was begun. Phosphor screens were used as a secondary method of beamshape observation.

4. Several guns were checked using the phosphor screen method. Poor beam shape was observed, and the guns were checked for dimensional conformation to the present design. Some problems were identified in this regard, and redesigned tooling and parts were ordered to correct these problems.

2.2 Program Schedule

Figure 2-1 shows the Program Schedule, updated as of April 1979. The primary cause of slippage has been lack of a suitable method of measuring beam shape. This problem has been solved by the use of phosphor screens and the fabrication of a new slit diode array.

All other tasks are proceeding on schedule with one exception: because of results obtained by beam shape analysis performed as part of this program, emphasis has been shifted away from the development of the metal-ceramic version of the sheet beam gun and increased emphasis has been put on fabrication techniques using the present glass envelope configuration. For this reason, the two tasks having to do with development of the metal ceramic gun have been deleted from the program.

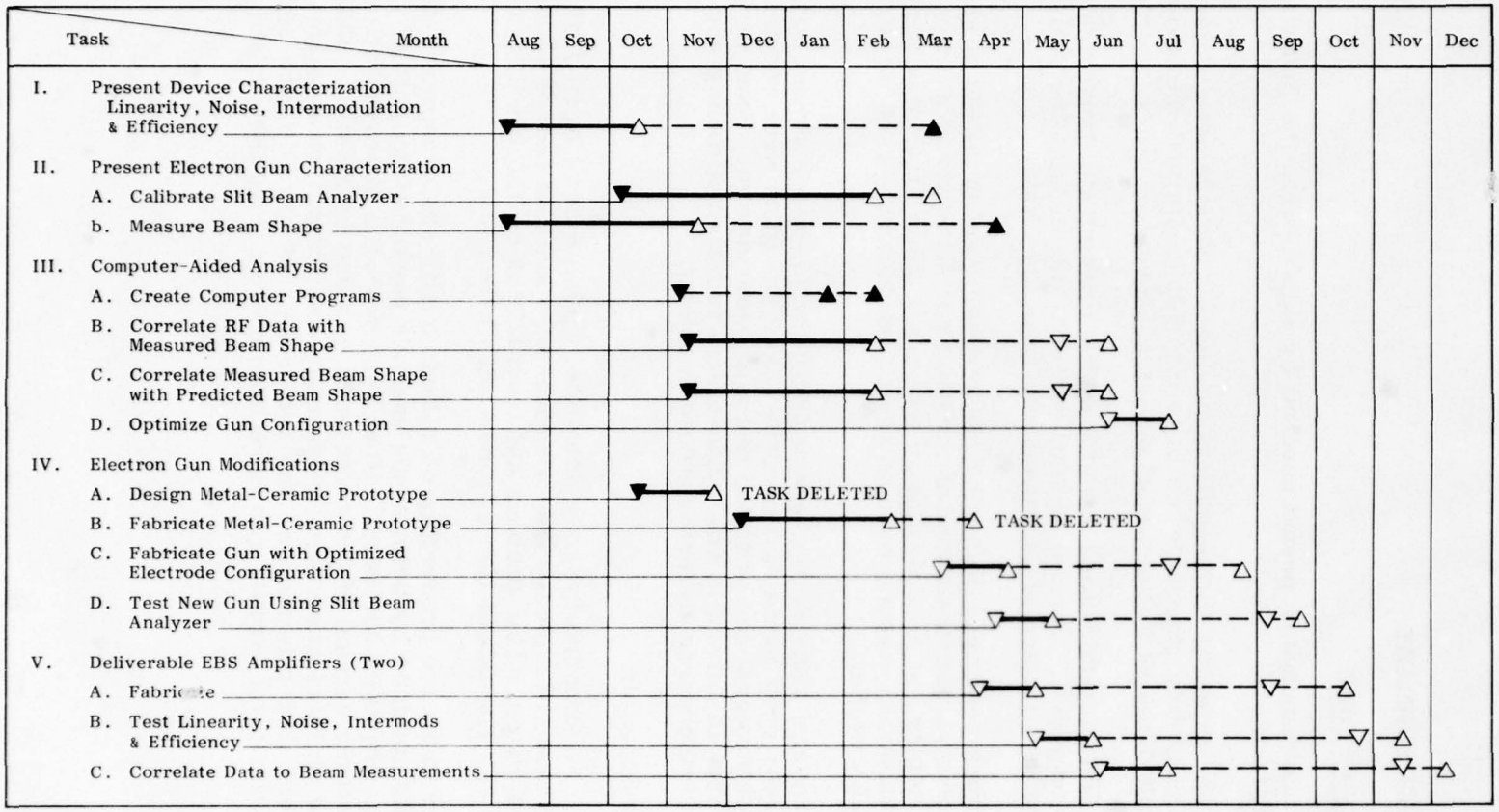

Figure 2-1. Program Milestone Schedule

3.0 CHARACTERIZATION OF EXISTING DEVICES

Extensive linearity and intermodulation measurements were performed on a deflected beam amplifier, WJ-3662-1 S/N 9. The device was set up for saturated output power of 46.0 dBm at maximum efficiency. The balanced two tone method of measurement was used, and in most cases, the fundamental tones and their 3rd, 5th, and 7th intermodulation products were measured over a 20-33 dB dynamic range. The parameter varied during these tests was the voltage on anode 3, the next to last anode in the gun stack. (Anode 4 is held at ground potential.) Figures 3-1 through 3-5 summarize these results, and Figure 3-6 expresses the tradeoff between linearity and efficiency. The criterion for linearity is the maximum 3rd order intermodulation product referenced to fundamental saturation level; note that the case for "best" linearity by this criterion ($A_3 = 3400$) is not coincident with the case where the fundamental deviates the least from constant gain ($A_3 = 3500$), nor with the case where single tone saturated efficiency is maximum ($A_3 = 3300$). The reason for this is attributed to the sidelobes present in the beam density profile, which has been observed on phosphor screens. At maximum efficiency, the amplifier is running in class C, i.e., with a tightly focused beam smaller than the diode spacing. At other points, class AB predominates, with current spillover severely reducing efficiency. Since the beam profile as predicted by computer for class C is not perfectly rectangular, the intermodulation products are more severe than for class AB, which in spite of spillover has a better beamshape within the width of the diode spacing.

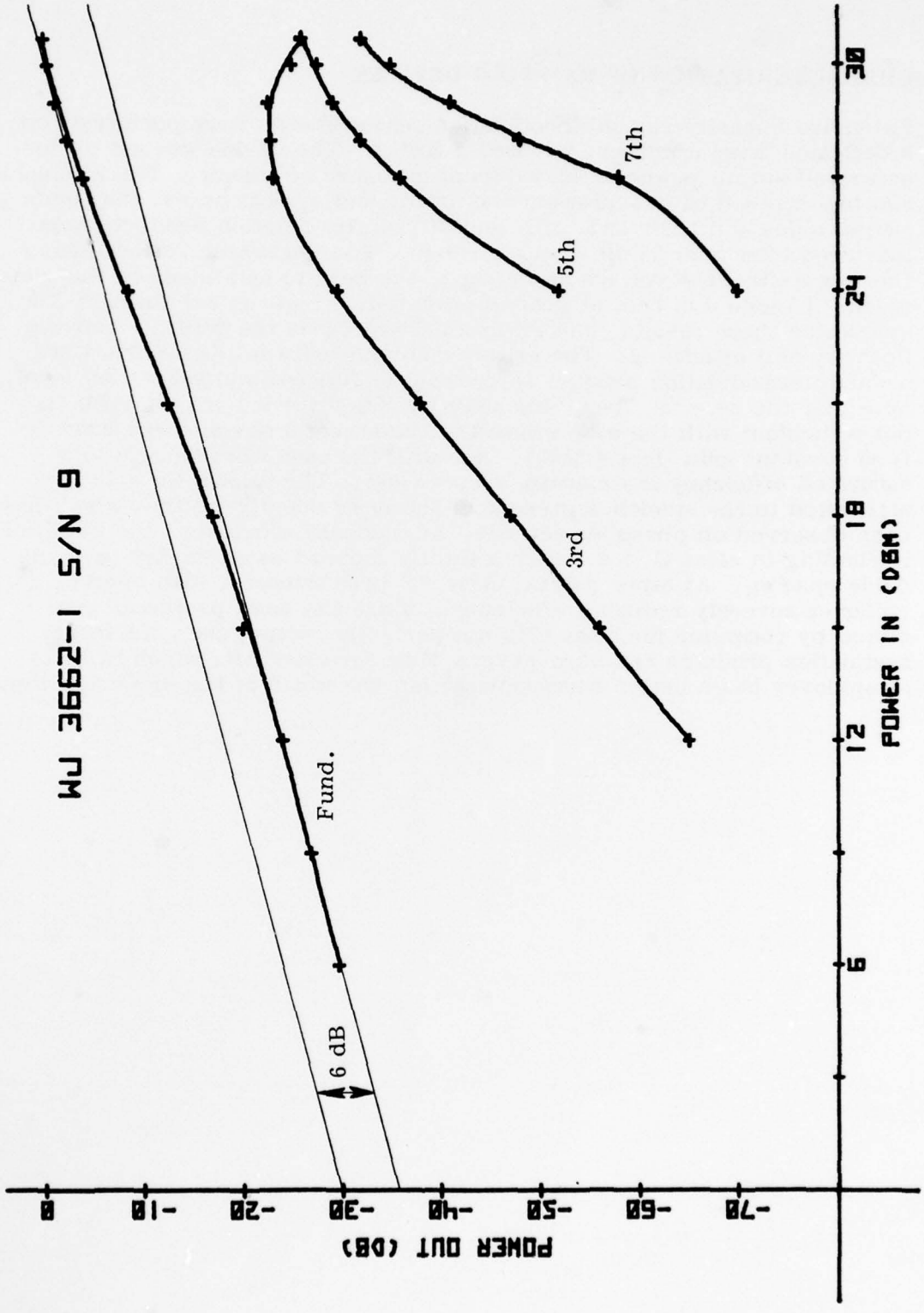

Figure 3-1. IMD Performance (A_3 = 3100 V).

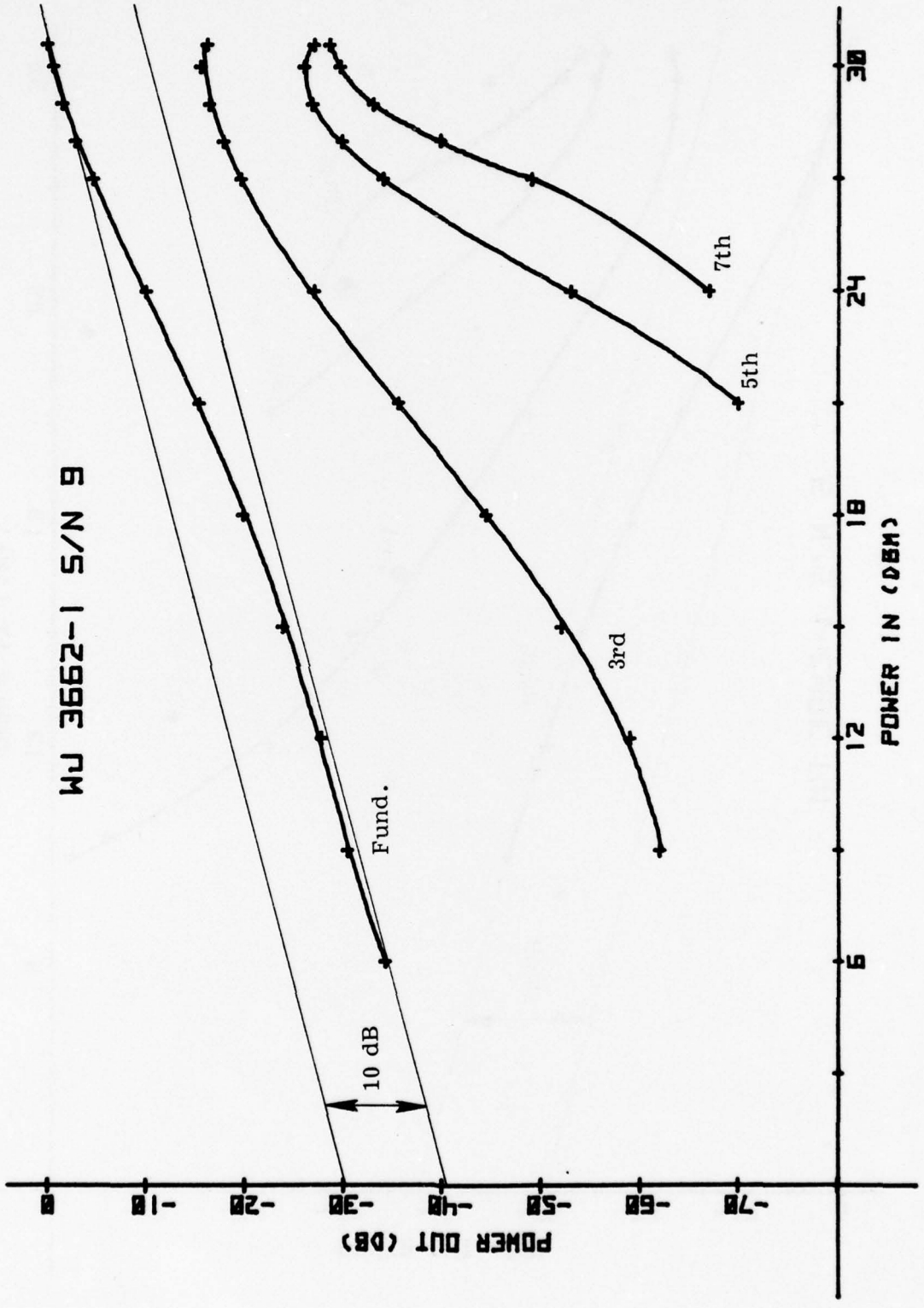

Figure 3-2. IMD Performance (A_3 = 3200 V).

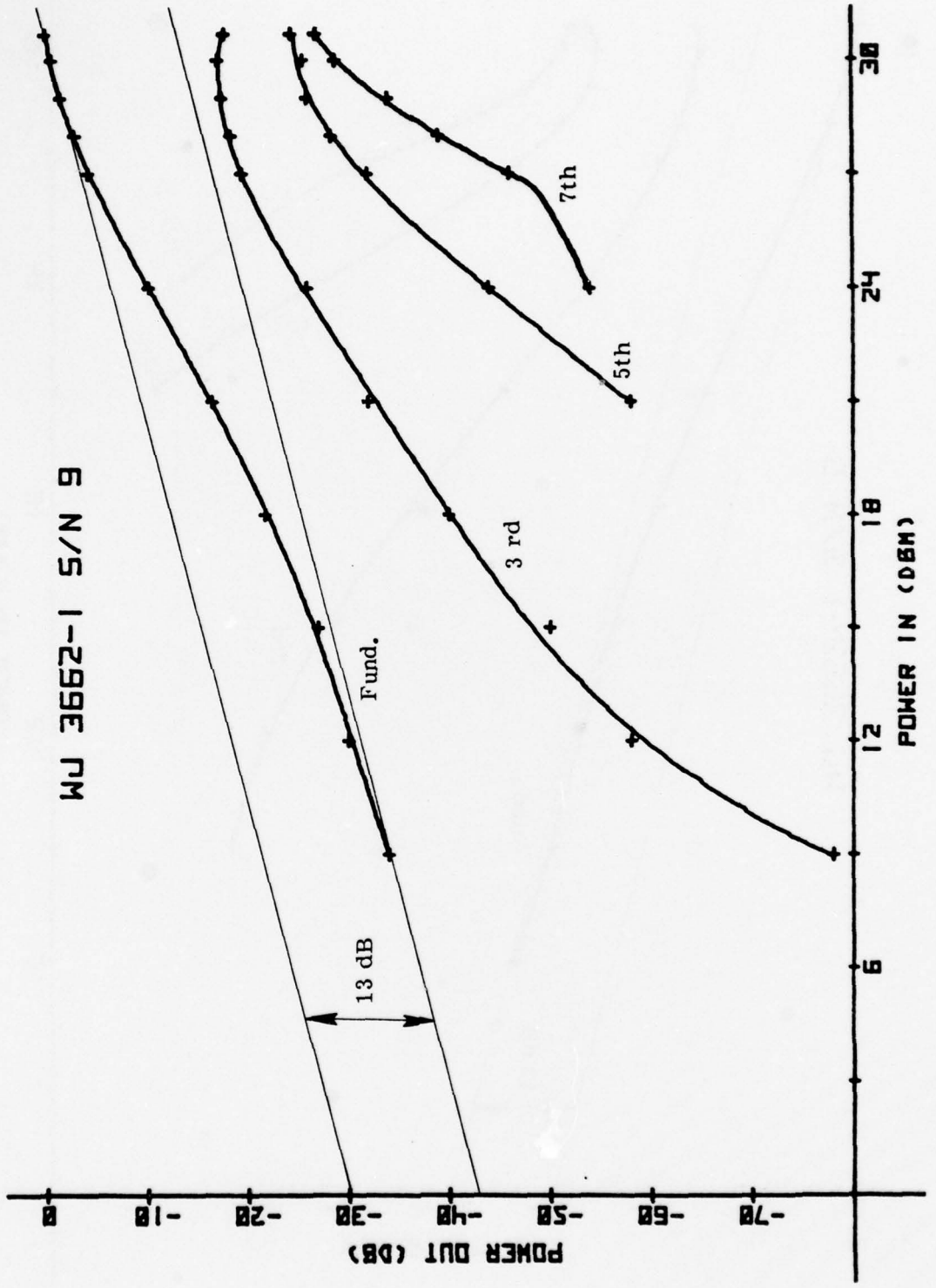

Figure 3-3. IMD Performance for the Case Where Maximum Target Efficiency Is Attained at Single Tone Saturation (A_3 = 3300 V).

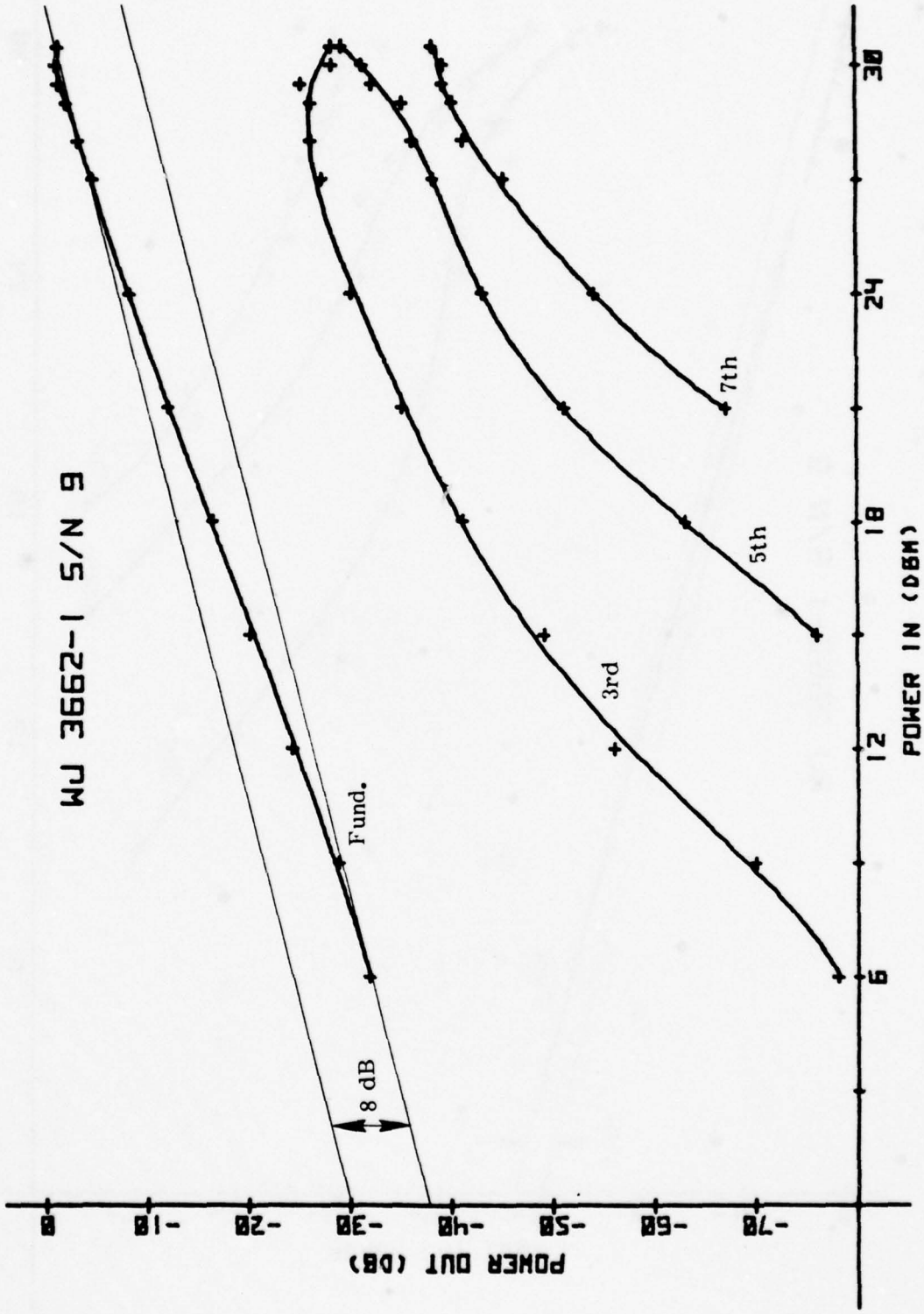

Figure 3-4. IMD Performance for the Case where Maximum 3rd Order IMD Is Minimized (A_3 = 3400 V).

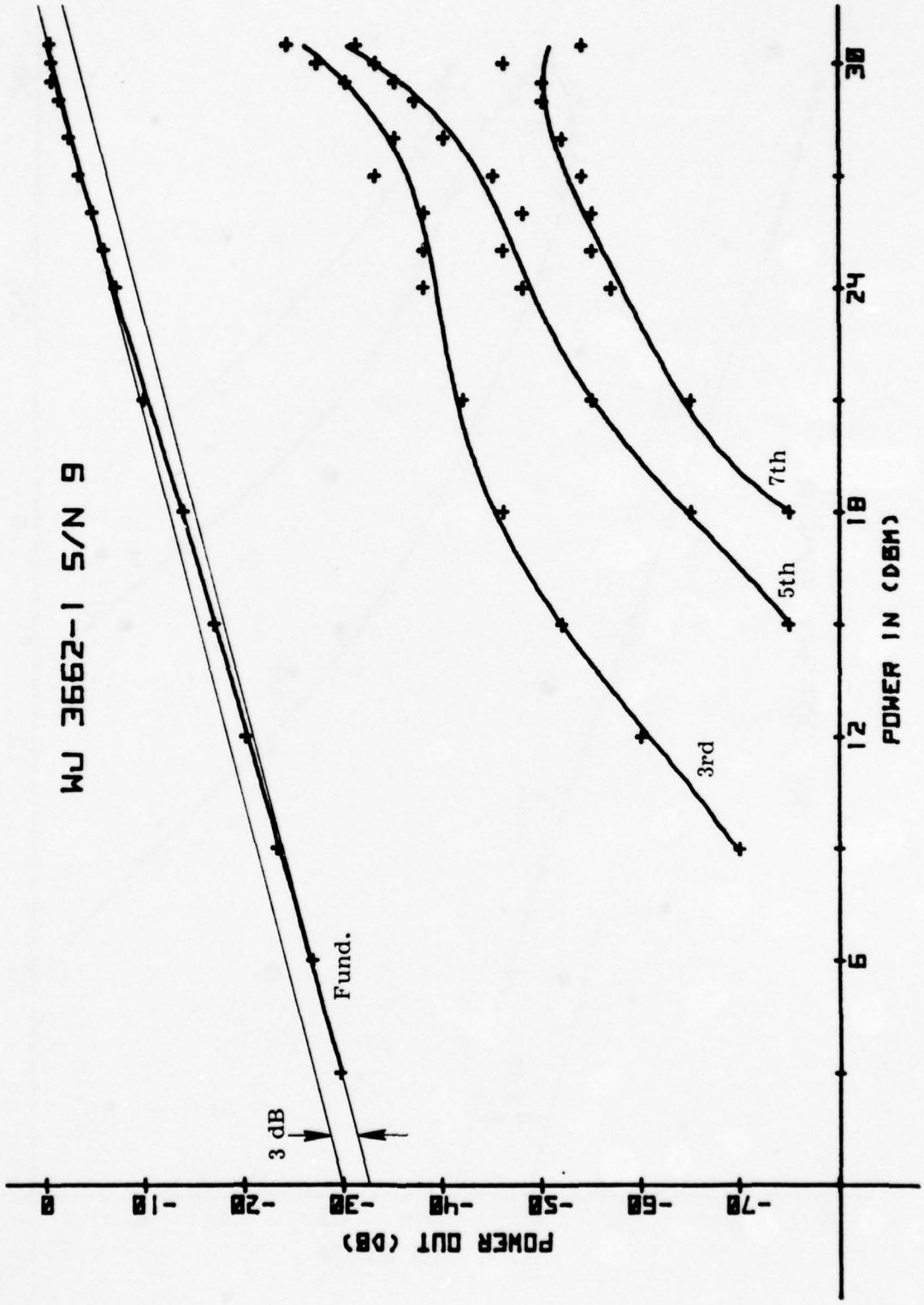

Figure 3-5. IMD Performance (A_3 = 3500 V).

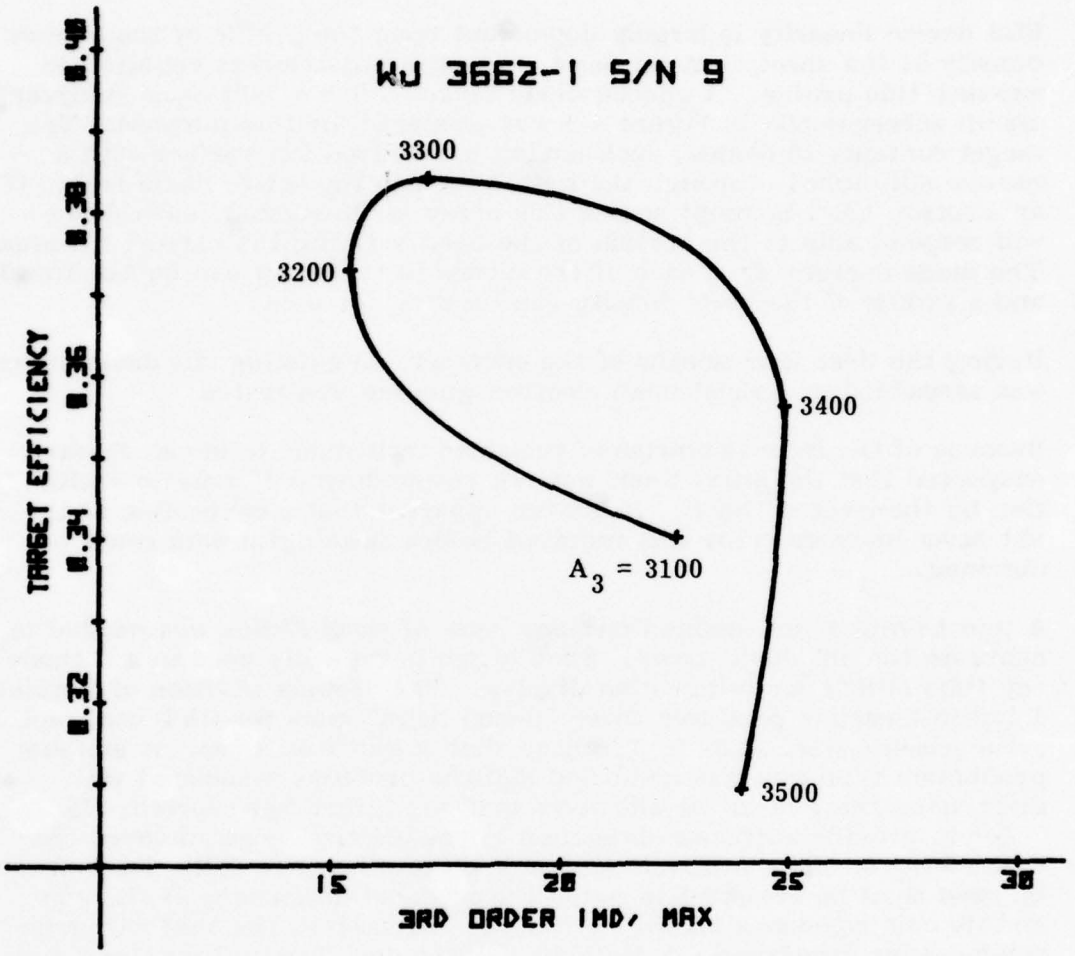

Figure 3-6. Linearity/Efficiency Tradeoff, expressed parametrically as a function of Anode 3 voltage.

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4.0 MEASUREMENT OF ELECTRON BEAM SHAPE

4.1 Slit Diode Array

EBS device linearity is largely dependent upon the profile of the current density of the sheet electron beam. An accurate means is required to measure this profile. A special diode target called a "slit beam analyzer" shown schematically in Figure 4-1 was prepared for this purpose. The target contains 10 diodes, each having a metalized top surface with a narrow slit etched through the metalization to the active diode layer. If an electron beam is swept across this array as illustrated, each diode will respond only to the portion of the beam striking the narrow slit area. The diode current from each of the diodes in the array can be monitored and a profile of the beam density can be thus obtained.

During the first four months of the contract, an existing slit diode array was assembled to a sheet beam electron gun and was tested.

Because of the inconsistencies of response from diode to diode, it was suspected that the array itself was not responding uniformly to excitation by the electron beam. It became apparent that a calibration of the slit beam analyzer array was required before meaningful data could be obtained.

A gun having a well-defined circular beam of small radius was needed to calibrate the slit diode array. Such a gun is typically used in a cathode ray tube (CRT) for information display. The Stewart Division of Watkins-Johnson Company produces these "pencil beam" guns for CRT use, and arrangements were made to purchase such a gun from them. A suitable production type gun was identified and the problems associated with interfacing the gun to the slit beam analyzer target were solved. In order to provide sufficient deflection of the electron beam to cover the entire target, using available sawtooth generators, the deflection coil to be used must be designed to match the physical dimensions of the gun and its coil impedance should be roughly the same as the sawtooth generator output impedance. A suitable coil was designed and procured from an outside vendor.

When the pencil beam gun was operated with the slit diode array, the diode current obtained was insufficient to provide a high enough signal-to-noise ratio. In addition, problems were experienced in obtaining a reasonable amount of cathode current from the gun.

The gun was removed from the slit diode array and sent back to the Stewart Division for installation of a new cathode. In conjunction with

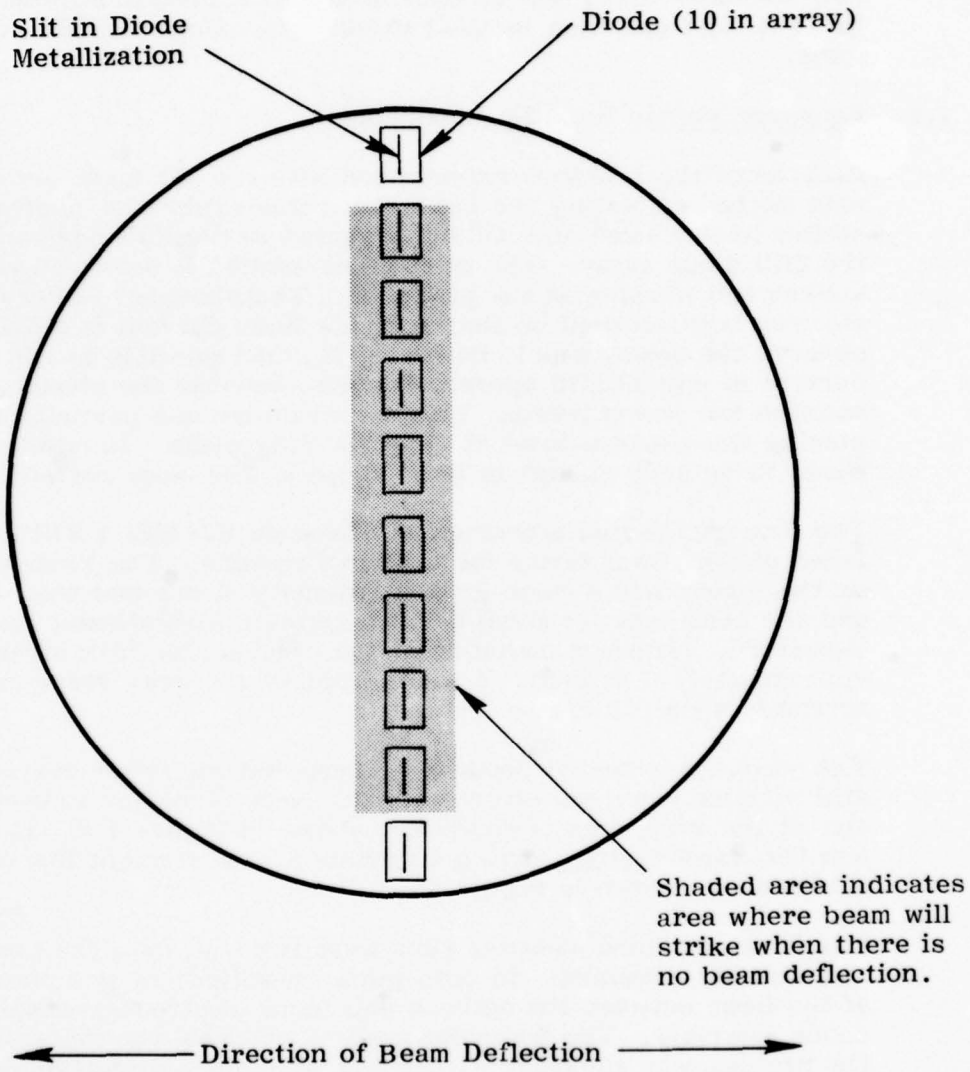

Figure 4-1. Slit Beam Analyzer Array

this, fabrication of a new slit diode array was begun, since several of the diodes in the slit diode array were not functioning.

The new slit diode array will have wider (0.002 inches) slits to provide greater response amplitude. Since the optimum beam width is 0.040 inches, resolution will still be far in excess of what is required. The new slit diode array will be first tested with the pencil beam gun to calibrate it, and can then be used to test beam shape on EBS sheet beam guns.

4.2 Phosphor Screen Beam Measurements

Because of the problems experienced with the slit diode array, an alternate method of testing the beam shape was explored. A phosphor screen similar to that used on a CRT is mounted to the EBS device in place of the EBS diode array. The beam cross-section is observed when the beam strikes and illuminates the phosphor. The phosphor is very sensitive to electron bombardment so that very low beam current is sufficient to observe the beam shape. However, it is not possible to run high beam current at normal EBS operating levels, because the phosphor is evaporated at low power levels. This disadvantage was partially alleviated by pulsing the electron beam at very low duty cycle. In addition, there seems to be little change in beam shape as the beam current is increased.

The first gun tested was originally used on WJ-3662-1 S/N 16, which failed at low power levels for unknown reasons. The beam shape shown on the screen had a much greater intensity at one end than at the other, and the beam was not straight but exhibited a significant amount of curvature. Maximum deviation of the beam center from straight line was approximately 0.04 inch. A photograph of the beam image on the phosphor screen is shown in Figure 4-2.

The second gun tested produced a beam having better overall shape, but still with too much curvature and with some increase in intensity and beam size at the very ends of the beam, shown in Figure 4-3. The third gun was the worst tested, having a deviation from straight line of approximately 0.05 inches, shown in Figure 4-4.

The first and third electron guns were removed from the phosphor screens and visually examined. In both guns, misalignment was noted in the plane of the beam between the cathode and focus electrode assembly and the anode assembly. The fixturing used to assemble the guns was checked and the problem was apparent – when the lengthwise dimension of the focus electrode assembly was increased in early 1978, the fixture had not been modified to take up the slack. New fixturing to correct the problem was ordered.

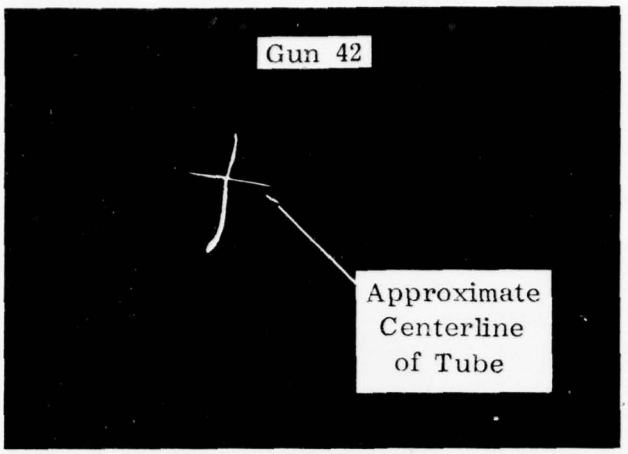

Figure 4.2 - Beam shape of gun #42 measured on a phosphor screen

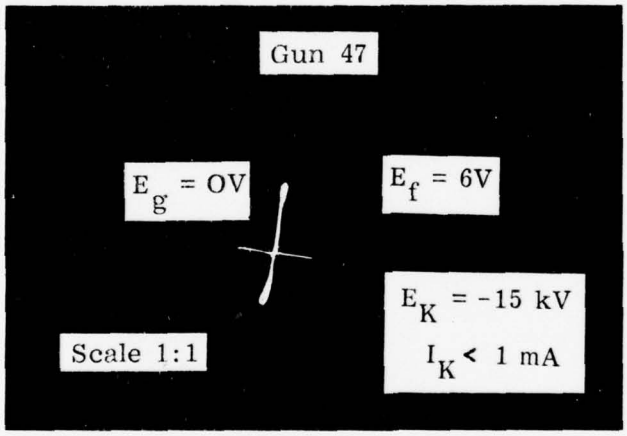

Figure 4.3 - Beam shape of gun #47 measured on phosphor screen.

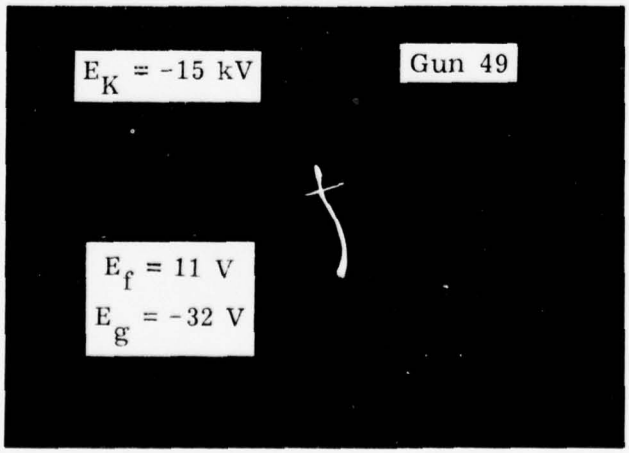

Figure 4.4 - Beam shape of gun #49 measured on a phosphor screen.

The last gun, which had the most pronounced beam curvature, also had a noticeable warpage in the first anode.

To reduce the "dogbone" effect of higher beam size and intensity near the ends of the beams, modifications were begun on the gun electrode designs. The modifications will increase the length of the slot in all the gun electrodes.

To increase the precision of the anodes themselves, a new method of fabricating the anodes was developed. Presently, each anode is machined to the desired dimensions. The new method involves machining each anode in two parts, placing the parts on a mandrel, and laser welding the two pieces together. Since the mandrel can be made with very good accuracy, the internal dimensions of the finished anode should be better using the new method.

5.0 COMPUTER AIDED ANALYSIS OF ELECTRON GUN

During the present reporting period, the final computer program was written to complete the correlation between the rectangular gun geometry and the Fourier components of the output signal. All of the programs currently used for gun analysis are listed in Table I. The first three perform the function of determining beam profile through the acceleration region, i.e., up to the meanderline. The fourth accounts for beamspread through the drift region, from the meanderline to the target. Finally, the last performs a convolution of the beam density profile with diode shape to determine the output waveform, then does a Fourier transform on this waveform to determine the spectral components and calculates the target efficiency for the fundamental.

The design of a new gun structure has typically involved the use of only the first two programs. Generally, the quality of the beamshape is quite obvious after the second program is run, and if there are severe problems with a design, there is no point in carrying out further calculations. For this reason, Parts (1) and (2) of Table I have been streamlined to run with one job submission. The remainder of the programs, however, take a great deal of effort to run, and are used only to check out a design that has been finalized from (2). A complete listing of all above programs is given in Appendices I through IV.

Table I

COMPUTER ELECTRON OPTICS PROGRAMS
AVAILABLE FOR GUN ANALYSIS

	Name	System	Language	Purpose	Author	Listing
1.	RCTGUN I	IBM VM370	FORTRAN	Equipotential locator to set up RCTGUN II	John Rettig	Appendix I
2.	RCTGUN II (XMGUN)	IBM VM370	FORTRAN	Slow region beam analysis	George Wada	(Proprietary)
3.	RCTGUN III	IBM VM370	FORTRAN	Fast region, large area beam analysis	John Rettig	Appendix II
4.	Beamspread	HP 9825A	HPL	Beamspread through drift space	John Rettig	Appendix III
5.	Convolve	HP 9825A	HPL	Beam density convolution, and FFT analysis of output waveform and efficiency calculation	Steve Brierley	Appendix IV

6.0 MODIFICATION TO ELECTRON GUN

Figure 6-1 and 6-2 illustrate the 2-dimensional beam profile resulting from the present electrode geometry and ideal Pierce geometry, respectively. Figure 6-2 has served as a model for the development of a new anode geometry, based on the following areas of improvement that have been identified from Figure 6-1:

1. The effective cathode location is not necessarily at the zero potential line.

2. The grid is biased negative relative to the cathode, in order to reduce emission. As mentioned previously, this crowds the emission density into the center of the cathode.

3. Potentials farther from the cathode are such that emission at the cathode can not be reduced without causing the beam area to be smaller, thereby increasing current density.

Problems (2) and (3) are being addressed by construction of a gridded anode in front of the cathode, which will take over the function of beam control and allow the focus anode to be run at or near cathode potential. Problem (1) is not being pursued at this time because the flexibility of the new geometry should allow small adjustments to be made on the focus anode potential, in order to satisfy the Pierce field characteristics. Note that the intent of the gridded anode is to shield the Pierce field region from the acceleration region of the gun, to prevent the lensing effects seen in Figure 6-1. The beam control function is a necessary side effect of the primary shielding function, and is predicted to require potentials of 100-200 volts relative to cathode.

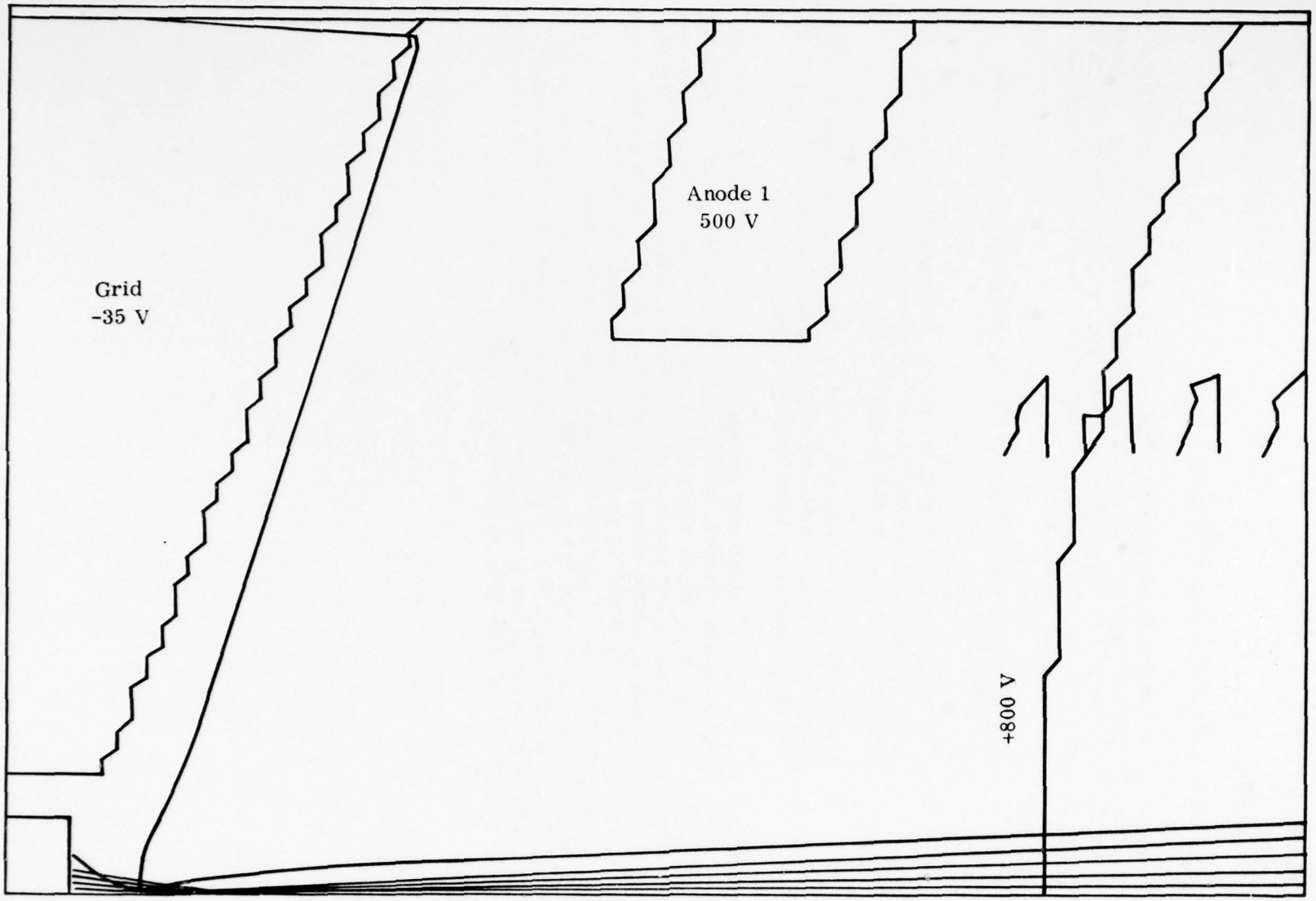

Figure 6-1. Part of the trajectory solution for the rectangular beam gun used in the 3662 Amplifier.

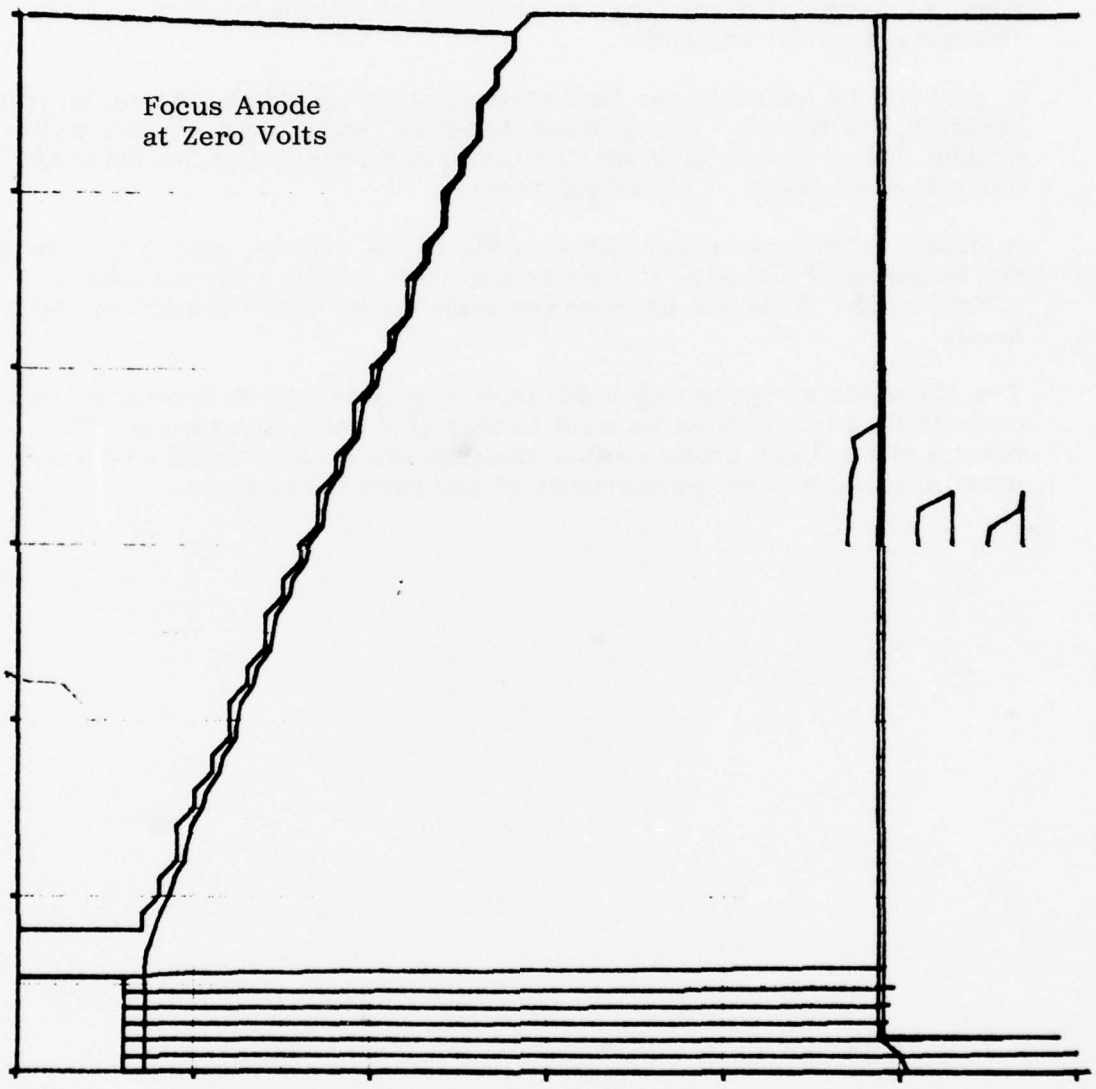

Figure 6-2. The Pierce Geometry Necessary to Draw a Uniform Beam Off the Cathode

7.0 PROGRAM FOR THE NEXT PERIOD

During the next four month period, effort will be directed at developing a method of producing election guns with improved cross-sectional profiles, by means of increasing the accuracy of the piece parts and the fixturing used for assembly.

A grid will be added to the first anode and the gridded gun will be constructed and tested. The gridded design should provide a more well-shaped beam because emission can take place over the entire cathode surface at all levels of cathode current.

Another modification which will be done to the existing gun is to increase the length of the anodes and focus electrode, leaving the cathode at 0.700 inches. This will improve the beam shape near the ends of the beam.

The slit diode array having 0.002 inch wide slits will be fabricated and calibrated, and will then be used to test EBS sheet beam guns. The results of the beam cross-section analysis will be correlated with measured intermodulation performance of the same electron gun.

Appendix I

RCTGUN I

```
C                                                                       GUN00010
C .....................................................................  GUN00020
C                                                                       GUN00030
C                                                                       GUN00040
C        RECTANGULAR GUN ANALYSIS PACKAGE                               GUN00050
C                                                                       GUN00060
C        JOHN B RETTIG       1/31/79                                    GUN00070
C                                                                       GUN00080
C                                                                       GUN00090
C        MAIN DRIVER ROUTINE, PART I - EQUIPOTENTIAL SOLUTIONS          GUN00100
C                                                                       GUN00110
      IMPLICIT REAL*8 (A-H,O-Z)                                         GUN00120
      REAL*8 V(41,401)                                                  GUN00130
      REAL*8 COND(9)                                                    GUN00140
      REAL*8 X(200),Y(200),UX(200),UY(200)                              GUN00150
      REAL*8 TITLE(4)                                                   GUN00160
      INTEGER ICOND(9)                                                  GUN00170
      COMMON /A/ V                                                      GUN00180
      COMMON /B/ XMIN,XMAX,DXO,                                         GUN00190
     *           YMIN,YMAX,DYO,                                         GUN00200
     *           M,N,NXY                                                GUN00210
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        GUN00220
      COMMON /D/ X,Y,UX,UY                                              GUN00230
      COMMON /E/ TITLE                                                  GUN00240
      DATA BW /.2/                                                      GUN00250
      DATA NEQP /31/                                                    GUN00260
      DATA YEQP /4.5D-3/                                                GUN00270
      DATA RELERR /1.D-4/                                               GUN00280
      DATA ITER /20/                                                    GUN00290
      DATA X1,X2,Y1,Y2 /0.,4.D-3,0.,6.D-3/                              GUN00300
      DATA ENGMET /39.37/                                               GUN00310
C                                                                       GUN00320
C        READ IN INITIAL INFORMATION                                    GUN00330
C                                                                       GUN00340
      CALL INIT                                                         GUN00350
C                                                                       GUN00360
C        READ IN VOLTAGES FROM PREVIOUS RUN                             GUN00370
C                                                                       GUN00380
      READ(8) V                                                         GUN00390
C                                                                       GUN00400
C        READ IN CONDUCTOR CONFIGURATION                                GUN00410
C                                                                       GUN00420
      CALL MESH                                                         GUN00430
C                                                                       GUN00440
C        RELAX VOLTAGE MATRIX                                           GUN00450
C                                                                       GUN00460
      ERRMAX=RELERR*(CMAX-CMIN)                                         GUN00470
      CALL RELAX (1,1,ERROR,ERRMAX)                                     GUN00480
      IF (ERROR.LT.ERRMAX)  GO TO 4                                     GUN00490
      KSTEP=1                                                           GUN00500
    1 KSTEP=2*KSTEP                                                     GUN00510
      IF (MOD(M-1,KSTEP).NE.0)  GO TO 2                                 GUN00520
      IF (MOD(N-1,KSTEP).NE.0)  GO TO 2                                 GUN00530
      GO TO 1                                                           GUN00540
    2 KSTEP=KSTEP/2                                                     GUN00550
```

```
      CALL RELAX (ITER,KSTEP,ERROR,ERRMAX)                              GUN00560
      IF (ERROR.LT.ERRMAX)  GO TO 3                                     GUN00570
      CALL RELAX (ITER,1,ERROR,ERRMAX)                                  GUN00580
C                                                                       GUN00590
C        RECORD V MATRIX FOR NEXT USAGE                                 GUN00600
C                                                                       GUN00610
  3   REWIND 8                                                          GUN00620
      WRITE(8) V                                                        GUN00630
  4   WRITE(1,100)  ERROR                                               GUN00640
C                                                                       GUN00650
C        PLOT CONTOURS                                                  GUN00660
C                                                                       GUN00670
      CALL CONPLT (BW,NEQP)                                             GUN00680
C                                                                       GUN00690
C        DETERMINE EQUIPOTENTIAL SURFACE IN VICINITY OF Y=YEQP          GUN00700
C                                                                       GUN00710
      V0=PINT(X1,Y1+.75*(Y2-Y1))-COFF                                   GUN00720
      CALL EQPTL (V0,X1,X2,Y1,Y2)                                       GUN00730
C                                                                       GUN00740
C        WRITE OUT THEN CONVERT TO INCHES                               GUN00750
C                                                                       GUN00760
      WRITE(1,101)  V0                                                  GUN00770
      DO 10  I=1,NXY                                                    GUN00780
      WRITE(1,102)  X(I),Y(I)                                           GUN00790
      X(I)=X(I)*ENGMET                                                  GUN00800
      Y(I)=Y(I)*ENGMET                                                  GUN00810
 10   CONTINUE                                                          GUN00820
C                                                                       GUN00830
C        GENERATE INPUT FILE FOR XMGUN                                  GUN00840
C                                                                       GUN00850
      WRITE(2,103)  TITLE(3),V0,V0                                      GUN00860
      X(1)=X(2)                                                         GUN00870
      Y(1)=.2125                                                        GUN00880
      NCARDS=1+(NXY-1)/7                                                GUN00890
      WRITE(2,104)  NCARDS,COND(2),COND(3)                              GUN00900
      DO 20  I=1,NXY,7                                                  GUN00910
      JF=MIN0(8,NXY+1-I)                                                GUN00920
      WRITE(2,105)  (Y(NXY+2-I-J),X(NXY+2-I-J),J=1,JF)                  GUN00930
 20   CONTINUE                                                          GUN00940
      WRITE(2,106)                                                      GUN00950
      STOP                                                              GUN00960
100   FORMAT (///' MAXIMUM CHANGE IN MESH ON LAST ITERATION = ',D12.4)  GUN00970
101   FORMAT (///' COORDINATES IN METERS OF EQUIPOTENTIAL LINE ',       GUN00980
     *             ' V0 = ',D12.4//6X,'X',11X,'Y'/)                     GUN00990
102   FORMAT (2D12.4)                                                   GUN01000
103   FORMAT (A8,2X,2F10.0,'     .10   6  2  2  100  60 10001001100',6X,GUN01010
     *          '6.'/'.21251000..0115.015 .0115.050 .0115.100 .0115')  GUN01020
104   FORMAT ('3',9X,I2,' 2',6X,2('1'F9.0))                             GUN01030
105   FORMAT (8(2F5.4))                                                 GUN01040
106   FORMAT ('.0   .200 .0   .017 .0149.017 .42911.017'                GUN01050
     *       /'.41421.081.1041.1254.1041.0807.119 .0807.44391.081'      GUN01060
     *       /3('.0',8X),'1.         .0        -.009875')               GUN01070
      END                                                               GUN01080
C                                                                       INI00010
C .....................................................................  INI00020
```

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C                                                                       INI00030
      SUBROUTINE INIT                                                   INI00040
C                                                                       INI00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               INI00060
C                                                                       INI00070
C        JOHN B RETTIG       1/31/79                                    INI00080
C                                                                       INI00090
C                                                                       INI00100
C        DATA INITIALIZATION ROUTINE                                    INI00110
C                                                                       INI00120
      IMPLICIT REAL*8 (A-H,O-Z)                                         INI00130
      REAL*8 V(41,401)                                                  INI00140
      REAL*8 COND(9)                                                    INI00150
      REAL*8 TITLE(4)                                                   INI00160
      INTEGER ICOND(9)                                                  INI00170
      INTEGER NCHAR(9),LINE(120),SPACE                                  INI00180
      DATA NCHAR /1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                  INI00190
      DATA SPACE /1H /                                                  INI00200
      COMMON /A/ V                                                      INI00210
      COMMON /B/ XMIN,XMAX,DX0,                                         INI00220
     *           YMIN,YMAX,DY0,                                         INI00230
     *           M,N,NXY                                                INI00240
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        INI00250
      COMMON /E/ TITLE                                                  INI00260
      DATA CMIN0 /1.D4/                                                 INI00270
C                                                                       INI00280
C        DATA DECK SETUP ON LOGICAL RECORD 3  (ALL UNITS MKS)           INI00290
C                                                                       INI00300
C        CARD    VARIABLE        FORMAT      DESCRIPTION               INI00310
C                                                                       INI00320
C         1       TITLE(1-2)     2A8      IDENTIFICATION                INI00330
C                                                                       INI00340
C         2       TITLE(3-4)     2A8      TITLE                         INI00350
C                                                                       INI00360
C         3         M,N          2I5      V MESH SIZE                   INI00370
C                                                                       INI00380
C         4       DX0,DY0        2D12.2   V MESH INCREMENTS (M)         INI00390
C                                                                       INI00400
C        5-13     ICOND,COND   I1,3X,   CONDUCTOR CODES - ICOND IS      INI00410
C                               F6.0     THE CHARACTER USED IN THE MESH INI00420
C                                        TO REPRESENT POTENTIAL COND    INI00430
C                                        (9 OR LESS MAY BE SPECIFIED)   INI00440
C                                                                       INI00450
C        LAST                                (END OF RECORD CARD)       INI00460
C                                                                       INI00470
C                                                                       INI00480
      READ(3,100) (TITLE(I),I=1,4),M,N                                  INI00490
      READ(3,101) DX0,DY0                                               INI00500
C                                                                       INI00510
C        ESTABLISH BOUNDARIES                                           INI00520
C                                                                       INI00530
      XMIN=0.                                                           INI00540
      XMAX=XMIN+DX0*DFLOAT(M-1)                                         INI00550
      YMIN=0.                                                           INI00560
      YMAX=YMIN+DY0*DFLOAT(N-1)                                         INI00570
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C                                                                       INI00580
C        WRITE OUT GEOMETRICAL AND INITIAL CONDITION INFORMATION        INI00590
C                                                                       INI00600
      WRITE(1,102)  (TITLE(I),I=1,4),M,N,                               INI00610
     *              XMIN,XMAX,DX0,                                      INI00620
     *              YMIN,YMAX,DY0                                       INI00630
C                                                                       INI00640
C        READ CONDUCTOR CODING AND POTENTIALS                           INI00650
C                                                                       INI00660
      DO 10  I=1,9                                                      INI00670
      NCOND=I                                                           INI00680
      READ(3,103,END=11) ICOND(I),COND(I)                               INI00690
 10   CONTINUE                                                          INI00700
C                                                                       INI00710
 11   NCOND=NCOND-1                                                     INI00720
C                                                                       INI00730
C        CALCULATE MAX, MIN, AND OFFSET                                 INI00740
C                                                                       INI00750
      CMIN=COND(1)                                                      INI00760
      CMAX=COND(1)                                                      INI00770
C                                                                       INI00780
      DO 20  I=1,NCOND                                                  INI00790
      IF (CMIN.GT.COND(I))  CMIN=COND(I)                                INI00800
      IF (CMAX.LT.COND(I))  CMAX=COND(I)                                INI00810
 20   CONTINUE                                                          INI00820
      COFF=CMIN0-CMIN                                                   INI00830
      RETURN                                                            INI00840
C                                                                       INI00850
100   FORMAT (2A8/2A8/2I5)                                              INI00860
101   FORMAT (3D12.4)                                                   INI00870
102   FORMAT (/////10X,'IDENT      ',2A8//10X,'TITLE      ',2A8///     INI00880
     *    ' MESH SIZE IS ',I3,' * ',I3,' POINTS'//                     INI00890
     *    ' XMIN = ',D10.4,10X,'XMAX = ',D10.4,10X,'XINC = ',D10.4,    INI00900
     *    ' METERS'//                                                  INI00910
     *    ' YMIN = ',D10.4,10X,'YMAX = ',D10.4,10X,'YINC = ',D10.4,    INI00920
     *    ' METERS'//)                                                 INI00930
103   FORMAT (I1,3X,F6.0)                                               INI00940
      END                                                               INI00950
C                                                                       MES00010
C .....................................................................  MES00020
C                                                                       MES00030
      SUBROUTINE MESH                                                   MES00040
C                                                                       MES00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               MES00060
C                                                                       MES00070
C        JOHN B RETTIG      1/31/79                                     MES00080
C                                                                       MES00090
C        THIS ROUTINE SETS UP A BRAND NEW MESH OF CONDUCTORS IN THE     MES00100
C        POTENTIAL MATRIX V.  ADVANTAGE IS TAKEN OF ANY PREVIOUS        MES00110
C        SOLUTION OF A SIMILAR TYPE BY CHANGING ONLY THOSE MESH         MES00120
C        VALUES WHERE A NEW CONDUCTOR IS LOCATED.                       MES00130
C                                                                       MES00140
      IMPLICIT REAL*8 (A-H,O-Z)                                         MES00150
      REAL*8 V(41,401)                                                  MES00160
      REAL*8 COND(9)                                                    MES00170
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      INTEGER ICOND(9)                                                  MES00180
      INTEGER NCHAR(9),LINE(120),SPACE                                  MES00190
      DATA NCHAR /1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                  MES00200
      DATA SPACE /1H /                                                  MES00210
      COMMON /A/ V                                                      MES00220
      COMMON /B/ XMIN,XMAX,DX0,                                         MES00230
     *           YMIN,YMAX,DY0,                                         MES00240
     *           M,N,NXY                                                MES00250
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        MES00260
C                                                                       MES00270
C        DATA DECK SETUP ON LOGICAL RECORD 4 (CONDUCTOR GEOMETRY)       MES00280
C                                                                       MES00290
C        CARD    VARIABLE    FORMAT      DESCRIPTION                   MES00300
C                                                                       MES00310
C         1-N                  M*A1      CONDUCTOR MESH CODES          MES00320
C                                                                       MES00330
C        LAST                           (END OF RECORD CARD)           MES00340
C                                                                       MES00350
C                                                                       MES00360
C        READ IN CONDUCTOR INFORMATION                                  MES00370
C                                                                       MES00380
      DO 20  J=1,N                                                      MES00390
      READ(4,100) (LINE(I),I=1,M)                                       MES00400
      DO 10  I=1,M                                                      MES00410
      V(I,J) = DMAX1(DABS(V(I,J)),CMIN0)                                MES00420
      IF (LINE(I).EQ.SPACE)  GO TO 10                                   MES00430
      DO 11  K=1,9                                                      MES00440
      K0=K                                                              MES00450
      IF (LINE(I).EQ.NCHAR(K0))  GO TO 12                               MES00460
 11   CONTINUE                                                          MES00470
      GO TO 30                                                          MES00480
 12   DO 13  K=1,NCOND                                                  MES00490
      K1=K                                                              MES00500
      IF(K0.EQ.ICOND(K1))  GO TO 14                                     MES00510
 13   CONTINUE                                                          MES00520
      GO TO 30                                                          MES00530
 14   V(I,J)= -(COND(K1)+COFF)                                          MES00540
 10   CONTINUE                                                          MES00550
 20   CONTINUE                                                          MES00560
      RETURN                                                            MES00570
 30   WRITE(1,101)  J,I,(LINE(I),I=1,M)                                 MES00580
      STOP                                                              MES00590
C                                                                       MES00600
100   FORMAT (120A1)                                                    MES00610
101   FORMAT (/////' INPUT MESH ERROR',10X,' LINE ',I5,                 MES00620
     *          10X,' CHARACTER ',I5//1X,120A1)                        MES00630
      END                                                               MES00640
C                                                                       REL00010
C .....................................................................  REL00020
C                                                                       REL00030
      SUBROUTINE RELAX (ITER,KSTEP0,ERROR,ERRMAX)                       REL00040
C                                                                       REL00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               REL00060
C                                                                       REL00070
C        JOHN B RETTIG      1/31/79                                     REL00080
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C                                                                       REL00090
C                                                                       REL00100
C       THIS ROUTINE IMPLEMENTS THE 4-NODE DISCRETIZED LAPLACIAN        REL00110
C       OPERATOR TO SOLVE LAPLACE'S EQUATION WITHIN A SPECIFIED         REL00120
C       M*N MESH.  A SUCCESSIVE OVERRELAXATION TECHNIQUE IS             REL00130
C       EMPLOYED TO PROVIDE FAST CONVERGENCE, ALONG WITH A SCHEME       REL00140
C       THAT STARTS WITH A COARSE MESH AND SUCCESSIVELY WORKS TO        REL00150
C       THE FINE MESH (I.E. EVERY SINGLE MESH POINT).  THE LARGEST      REL00160
C       OF MESH GRADES EMPLOYED IS SPECIFIED BY KSTEP, WITH THE         REL00170
C       RESTRICTION THAT KSTEP BE AN INTEGRAL DIVISOR OF BOTH (M-1)     REL00180
C       AND (N-1).  AFTER EACH COARSE RELAXATION IS COMPLETE, THE       REL00190
C       NEXT FINER MESH IS INTERPOLATED LINEARLY.  THIS INTERPOLATION   REL00200
C       IS PERFORMED USING A FOUR NEAREST NEIGHBOR CALCULATION FIRST    REL00210
C       FOR THOSE POINTS FALLING AT DISTANCE SQRT(2) FROM THE COARSE    REL00220
C       MESH, AND THEN FOR THOSE POINTS FALLING AT DISTANCE (.5)        REL00230
C       FROM THE COARSE MESH.                                           REL00240
C       THE LAST FEW STEPS FOR THE FINEST GRADE MESH (KSTEP=1)          REL00250
C       RELAXATION ARE GAUSS-SEIDEL (W=.25) IN ORDER TO SMOOTH OUT      REL00260
C       THE ROUGH EDGES LEFT OVER FROM THE OVERRELAXATION.              REL00270
C                                                                       REL00280
C       IF KSTEPO=1, ONLY KSTEP=1 IS USED, AND THE PROGRAM WILL         REL00290
C       REPEAT UNTIL ERROR<ERRMAX.  OTHERWISE, MORE COARSE MESHES ARE   REL00300
C       USED TO START, WORKING TO THE FINER MESH AND REPEATING THIS     REL00310
C       FINE MESH UNTIL ERROR<ERRMAX.  USE CAUTION WHEN CHOOSING ERRMAXREL00320
C       AS A 41*401 MESH TAKES ABOUT 4-5 MINUTES ON AN IBM 370/148      REL00330
C       WITH ERRMAX SET TO .01 PERCENT OF THE MAXIMUM LESS MINIMUM      REL00340
C       MESH POTENTIALS.                                                REL00350
C                                                                       REL00360
C       SEE CARNAHAN, LUTHER, AND WILKES, APPLIED NUMERICAL             REL00370
C       METHODS, WILEY,1969, OR FORSYTHE AND WASOW, FINITE DIFFER-      REL00380
C       ENCE METHODS FOR PDE, WILEY, 1960.                              REL00390
C                                                                       REL00400
C       IF THE MESH IS NOT ENCLOSED BY CONDUCTORS, PERIODICITY OF       REL00410
C       THE SOLUTION IS ASSUMED AND THE BOUNDARIES ARE FOLDED OVER      REL00420
C       (I.E. MIRROR IMAGE SYMMETRY IS ASSUMED).  IF THIS CANNOT        REL00430
C       BE TOLERATED, BE SURE TO SPECIFY CONDUCTORS ALL THE WAY         REL00440
C       AROUND THE MESH.                                                REL00450
C                                                                       REL00460
      IMPLICIT REAL*8 (A-H,O-Z)                                         REL00470
      REAL*8 V(41,401)                                                  REL00480
      COMMON /A/ V                                                      REL00490
      COMMON /B/ XMIN,XMAX,DXO,                                         REL00500
     *           YMIN,YMAX,DYO,                                         REL00510
     *           M,N,NXY                                                REL00520
C                                                                       REL00530
C       MESH COARSENESS LOOP                                            REL00540
C                                                                       REL00550
      KSTEP=2*KSTEPO                                                    REL00560
    1 KSTEP=MAXO(1,KSTEP/2)                                             REL00570
      KOFF=KSTEP                                                        REL00580
      T=3.14159/DFLOAT(MINO(M/KSTEP,N/KSTEP))                           REL00590
      W=0.5/(1.+DSIN(T))                                                REL00600
      IF (KSTEPO.EQ.1)  W=.25                                           REL00610
      LMAX=ITER/KSTEP                                                   REL00620
      IO=1                                                              REL00630
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      IF=M                                                              REL00640
      JO=1                                                              REL00650
      JF=N                                                              REL00660
C                                                                       REL00670
C        RELAXATION LOOP                                                REL00680
C                                                                       REL00690
      DO 30  L=1,LMAX                                                   REL00700
      ERROR=0.                                                          REL00710
      DO 20  I=IO,IF,KSTEP                                              REL00720
      IUP=I+KOFF                                                        REL00730
      IDN=I-KOFF                                                        REL00740
      IF (I.EQ.M)  IUP=IDN                                              REL00750
      IF (I.EQ.1)  IDN=IUP                                              REL00760
      DO 10  J=JO,JF,KSTEP                                              REL00770
      VO=V(I,J)                                                         REL00780
      IF(VO.LT.0.) GO TO 10                                             REL00790
      JUP=J+KOFF                                                        REL00800
      JDN=J-KOFF                                                        REL00810
      IF (J.EQ.N)  JUP=JDN                                              REL00820
      IF (J.EQ.1)  JDN=JUP                                              REL00830
      VOFF=W*(DABS(V(IDN,J))-VO+DABS(V(IUP,J))-VO                       REL00840
     *       +DABS(V(I,JDN))-VO+DABS(V(I,JUP))-VO)                      REL00850
      V(I,J)=VO+VOFF                                                    REL00860
      ERROR=DMAX1(ERROR,DABS(VOFF))                                     REL00870
   10 CONTINUE                                                          REL00880
   20 CONTINUE                                                          REL00890
      WRITE(6,200)  L,KSTEP,W,ERROR                                     REL00900
C                                                                       REL00910
C        RETURN IF ERROR SATISFIED WITH FINEST MESH AND GAUSS-SEIDEL    REL00920
C        HAS BEEN PERFORMED                                             REL00930
C                                                                       REL00940
      IF (KSTEP.EQ.1.AND.ERROR.LT.ERRMAX.AND.W.EQ..25)  RETURN          REL00950
C                                                                       REL00960
C        IF ALMOST COMPLETE, SWITCH TO GAUSS-SEIDEL                     REL00970
C                                                                       REL00980
      IF (ERROR.LT.10.*ERRMAX.AND.KSTEP.EQ.1)  W=.25                    REL00990
C                                                                       REL01000
   30 CONTINUE                                                          REL01010
C                                                                       REL01020
C        CHECK IF INTERPOLATION NECESSARY FOR NEXT FINER MESH           REL01030
C        OR IF COMPLETED                                                REL01040
C                                                                       REL01050
      IF (KSTEP0.EQ.1)  RETURN                                          REL01060
      IF (KSTEP.EQ.1)  GO TO 1                                          REL01070
C                                                                       REL01080
C        INTERPOLATE INBETWEEN POINTS                                   REL01090
C                                                                       REL01100
      KOFF=KSTEP/2                                                      REL01110
      IO=1+KOFF                                                         REL01120
      IF=M-KOFF                                                         REL01130
      JO=1+KOFF                                                         REL01140
      JF=N-KOFF                                                         REL01150
C                                                                       REL01160
C                                                                       REL01170
C                                                                       REL01180
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      DO 50  J=JO,JF,KSTEP                                              REL01190
      JUP=J+KOFF                                                        REL01200
      JDN=J-KOFF                                                        REL01210
      DO 40  I=IO,IF,KSTEP                                              REL01220
      IF (V(I,J).LT.0.)  GO TO 40                                       REL01230
      IUP=I+KOFF                                                        REL01240
      IDN=I-KOFF                                                        REL01250
      V(I,J)=.25*(DABS(V(IDN,JDN))+DABS(V(IUP,JDN))                     REL01260
     *           +DABS(V(IDN,JUP))+DABS(V(IUP,JUP)))                    REL01270
 40   CONTINUE                                                          REL01280
 50   CONTINUE                                                          REL01290
      IO=1+KOFF                                                         REL01300
      IF=M-KOFF                                                         REL01310
      JO=1                                                              REL01320
      JF=N                                                              REL01330
C                                                                       REL01340
C                                                                       REL01350
C                                                                       REL01360
      DO 70  J=JO,JF,KSTEP                                              REL01370
      JUP=J+KOFF                                                        REL01380
      JDN=J-KOFF                                                        REL01390
      IF (J.EQ.1)  JDN=JUP                                              REL01400
      IF (J.EQ.N)  JUP=JDN                                              REL01410
      DO 60  I=IO,IF,KSTEP                                              REL01420
      IF(V(I,J).LT.0.) GO TO 60                                         REL01430
      IUP=I+KOFF                                                        REL01440
      IDN=I-KOFF                                                        REL01450
      V(I,J)=.25*(DABS(V(IDN,J))+DABS(V(IUP,J))                         REL01460
     *           +DABS(V(I,JDN))+DABS(V(I,JUP)))                        REL01470
 60   CONTINUE                                                          REL01480
 70   CONTINUE                                                          REL01490
      IO=1                                                              REL01500
      IF=M                                                              REL01510
      JO=1+KOFF                                                         REL01520
      JF=N-KOFF                                                         REL01530
      DO 90  J=JO,JF,KSTEP                                              REL01540
      JUP=J+KOFF                                                        REL01550
      JDN=J-KOFF                                                        REL01560
      DO 80  I=IO,IF,KSTEP                                              REL01570
      IF(V(I,J).LT.0.) GO TO 80                                         REL01580
      IUP=I+KOFF                                                        REL01590
      IDN=I-KOFF                                                        REL01600
      IF (I.EQ.M)  IUP=IDN                                              REL01610
      IF (I.EQ.1)  IDN=IUP                                              REL01620
      V(I,J)=.25*(DABS(V(IDN,J))+DABS(V(IUP,J))                         REL01630
     *           +DABS(V(I,JDN))+DABS(V(I,JUP)))                        REL01640
 80   CONTINUE                                                          REL01650
 90   CONTINUE                                                          REL01660
      GO TO 1                                                           REL01670
200   FORMAT ('***',2I10,F10.4,F10.2)                                   REL01680
      END                                                               REL01690
C                                                                       CON00010
C .....................................................................  CON00020
C                                                                       CON00030
      SUBROUTINE CONPLT (BW,NEQP)                                       CON00040
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C                                                                       CON00050
C       RECTANGULAR GUN ANALYSIS PACKAGE                                CON00060
C                                                                       CON00070
C       JOHN B RETTIG       1/31/79                                     CON00080
C                                                                       CON00090
C                                                                       CON00100
C       THIS ROUTINE GENERATES A CONTOUR EQUIPOTENTIAL PLOT ON THE      CON00110
C       LINE PRINTER.  CONDUCTORS, CODED AS NEGATIVE NUMBERS IN THE     CON00120
C       MESH, ARE SYMBOLIZED BY DIGITS FROM 1-9, ACCORDING TO THE       CON00130
C       SCHEME SET UP IN THE ARRAYS ICOND AND COND.  OPEN SPACES        CON00140
C       ARE REPRESENTED BY LETTERS ACCORDING TO THE VALUES OF BW AND    CON00150
C       NEQP.  THE PARAMETER NEQP IS THE NUMBER OF DESIRED EQUI-        CON00160
C       POTENTIALS (MAXIMUM 48), WHILE BW IS A BANDWIDTH SPECIFIER.     CON00170
C       THE WAY THE PARAMETER BW WORKS IS BEST ILLUSTRATED BY AN        CON00180
C       EXAMPLE.                                                        CON00190
C                                                                       CON00200
C             ASSUME NEQP=4, BW=.10, AND 10 < V < 40                    CON00210
C                                                                       CON00220
C                  A       9 < V < 11                                   CON00230
C                  B      19 < V < 21                                   CON00240
C                  C      29 < V < 31                                   CON00250
C                  D      39 < V < 41                                   CON00260
C                                                                       CON00270
C             HOWEVER, IF BW=.50 WITH ALL ELSE THE SAME                 CON00280
C                                                                       CON00290
C                  A     7.5 < V < 12.5                                 CON00300
C                  B    17.5 < V < 22.5                                 CON00310
C                  C    27.5 < V < 32.5                                 CON00320
C                  D    37.5 < V < 42.5                                 CON00330
C                                                                       CON00340
C       THUS, BW=0 WILL PRINT A BLANK PAGE, AND BW=1 WILL PRINT A       CON00350
C       SOLID PAGE OF CHARACTERS.                                       CON00360
C                                                                       CON00370
C       THE PARAMETER NEQP MIGHT BE ADJUSTED BY THE PROGRAM TO          CON00380
C       OBTAIN AESTHETIC EQUIPOTENTIAL SPACINGS.                        CON00390
C                                                                       CON00400
      IMPLICIT REAL*8 (A-H,O-Z)                                         CON00410
      REAL*8 V(41,401)                                                  CON00420
      REAL*8 COND(9)                                                    CON00430
      INTEGER ICOND(9)                                                  CON00440
      COMMON /A/ V                                                      CON00450
      COMMON /B/ XMIN,XMAX,DXO,                                         CON00460
     *           YMIN,YMAX,DYO,                                         CON00470
     *           M,N,NXY                                                CON00480
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        CON00490
      DATA MAX /120/                                                    CON00500
      INTEGER NCHAR(9),ACHAR(48),SPACE,UNIONT,PRT(120)                  CON00510
      DATA NCHAR /1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                  CON00520
      DATA ACHAR /1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,                      CON00530
     *            1HJ,1HK,1HL,1HM,1HN,1HP,1HQ,1HR,                      CON00540
     *            1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ,                      CON00550
     *            1HA,1HB,1HC,1HD,1HE,1HF,1HG,1HH,                      CON00560
     *            1HJ,1HK,1HL,1HM,1HN,1HP,1HQ,1HR,                      CON00570
     *            1HS,1HT,1HU,1HV,1HW,1HX,1HY,1HZ/                      CON00580
      DATA SPACE /1H /, UNIONT /1H*/                                    CON00590
```

```
      VINC=(CMAX-CMIN)/DFLOAT(NEQP-1)                                   CON00600
      VLINC=DLOG10(VINC)                                                CON00610
      IEXP=IDINT(1.01*VLINC)                                            CON00620
      IFRCT=IDINT(1.01*10.**(VLINC-DFLOAT(IEXP)))                       CON00630
      IF (IFRCT.EQ.7.OR.IFRCT.EQ.9)  IFRCT=IFRCT+1                      CON00640
      VINC=DFLOAT(IFRCT)*10.**IEXP                                      CON00650
      IMIN=IDINT(1.001*CMIN/VINC)                                       CON00660
      IMAX=1+IDINT(.999*CMAX/VINC)                                      CON00670
      NEQP=IMAX-IMIN+1                                                  CON00680
      WRITE(1,100)                                                      CON00690
      DO 10  I=1,NCOND                                                  CON00700
      WRITE(1,101)  ICOND(I),COND(I)                                    CON00710
   10 CONTINUE                                                          CON00720
      WRITE(1,102) BW                                                   CON00730
      DO 20  I=1,NEQP                                                   CON00740
      VCENT=DFLOAT(IMIN+I-1)*VINC                                       CON00750
      VLO=VCENT-VINC*BW/2.                                              CON00760
      VHI=VCENT+VINC*BW/2.                                              CON00770
      WRITE(1,103)  ACHAR(I),VLO,VCENT,VHI                              CON00780
   20 CONTINUE                                                          CON00790
      WRITE(1,104)                                                      CON00800
      MO=MIN0(MAX,M)                                                    CON00810
      IOFF=0                                                            CON00820
   40 DO 60  J=1,N                                                      CON00830
      DO 50  IO=1,MO                                                    CON00840
      I=IO+IOFF                                                         CON00850
      PRT(IO)=SPACE                                                     CON00860
      VO=V(I,J)                                                         CON00870
      IF (VO.LT.0.)  GO TO 51                                           CON00880
      V1=(VO-COFF)/VINC+BW/2.                                           CON00890
      IV1=IDINT(V1)                                                     CON00900
      IF(DABS(V1-DFLOAT(IV1)).GT.BW)  GO TO 50                          CON00910
      PRT(IO)=ACHAR(IV1-IMIN+1)                                         CON00920
      GO TO 50                                                          CON00930
   51 DO 52  K=1,NCOND                                                  CON00940
      KO=K                                                              CON00950
      IF (-VO.EQ.COND(KO)+COFF)  GO TO 53                               CON00960
   52 CONTINUE                                                          CON00970
      PRT(IO)=UNIDNT                                                    CON00980
      GO TO 50                                                          CON00990
   53 IV1=ICOND(KO)                                                     CON01000
      PRT(IO)=NCHAR(IV1)                                                CON01010
   50 CONTINUE                                                          CON01020
      WRITE(1,105)  (PRT(I),I=1,MO)                                     CON01030
   60 CONTINUE                                                          CON01040
      IF (MO+IOFF.GE.M)  RETURN                                         CON01050
      IOFF=IOFF+MO                                                      CON01060
      MO=MIN0(M-IOFF,MO)                                                CON01070
      WRITE(1,104)                                                      CON01080
      GO TO 40                                                          CON01090
  100 FORMAT (/////' ***** CONDUCTOR CODES *****'//                     CON01100
     *       10X,' CODE    VOLTS'/)                                     CON01110
  101 FORMAT (12X,I1,F12.2)                                             CON01120
  102 FORMAT (/////' ***** POTENTIAL CODES *****'//                     CON01130
     *       10X,' WINDOW = ',F6.4//                                    CON01140
```

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     *            ' CODE        LOW          MEAN         HIGH'/)                CON01150
103   FORMAT(2X,A1,4X,3F12.2)                                                     CON01160
104   FORMAT (1H1/1HQ)                                                            CON01170
105   FORMAT (1X,120A1)                                                           CON01180
      END                                                                         CON01190
C                                                                                 EQP00010
C ..................................................................              EQP00020
C                                                                                 EQP00030
      SUBROUTINE EQPTL (V0,X1,X2,Y1,Y2)                                           EQP00040
C                                                                                 EQP00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                                         EQP00060
C                                                                                 EQP00070
C        JOHN B RETTIG      1/31/79                                               EQP00080
C                                                                                 EQP00090
C                                                                                 EQP00100
C        THIS PROGRAM LOCATES AND PROVIDES COORDINATES FOR THE                    EQP00110
C        EQUIPOTENTIAL LINE OF VALUE V0, IN THE V MESH.  A LINEAR                 EQP00120
C        INTERPOLATION IS PERFORMED BETWEEN MESH POINTS.  IT IS                   EQP00130
C        ASSUMED THAT THE VOLTAGE MATRIX V IS STRICTLY MONOTONIC                  EQP00140
C        IN THE Y DIRECTION, WITHIN A REGION ABOUT THE EQUIPOTENTIAL              EQP00150
C        LINE.                                                                    EQP00160
C                                                                                 EQP00170
      IMPLICIT REAL*8 (A-H,O-Z)                                                   EQP00180
      REAL*8 V(41,401)                                                            EQP00190
      REAL*8 X(200),Y(200),UX(200),UY(200)                                        EQP00200
      COMMON /A/ V                                                                EQP00210
      COMMON /B/ XMIN,XMAX,DX0,                                                   EQP00220
     *           YMIN,YMAX,DY0,                                                   EQP00230
     *           M,N,NXY                                                          EQP00240
      REAL*8 COND(9)                                                              EQP00250
      INTEGER ICOND(9)                                                            EQP00260
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                                  EQP00270
      COMMON /D/ X,Y,UX,UY                                                        EQP00280
      V1=V0+COFF                                                                  EQP00290
      I1=MAX0(1,1+IDINT((X1-XMIN)/DX0))                                           EQP00300
      I2=MIN0(M,1+IDINT((X2-XMIN)/DX0))                                           EQP00310
      J1=MAX0(1,1+IDINT((Y1-YMIN)/DY0))                                           EQP00320
      J2=MIN0(N,1+IDINT((Y2-YMIN)/DY0))                                           EQP00330
      NXY=0                                                                       EQP00340
      DO 10  I=I1,I2                                                              EQP00350
      JDN=J1                                                                      EQP00360
      JUP=J2                                                                      EQP00370
      VDN=DABS(V(I,JDN))-V1                                                       EQP00380
      VUP=DABS(V(I,JUP))-V1                                                       EQP00390
      IF (VDN*VUP)  1,10,10                                                       EQP00400
1     JMD=(JDN+JUP)/2                                                             EQP00410
      VMD=DABS(V(I,JMD))-V1                                                       EQP00420
      IF (JDN.EQ.JMD)  GO TO 4                                                    EQP00430
      IF (VDN*VMD)  2,10,3                                                        EQP00440
2     JUP=JMD                                                                     EQP00450
      VUP=VMD                                                                     EQP00460
      GO TO 1                                                                     EQP00470
3     JDN=JMD                                                                     EQP00480
      VDN=VMD                                                                     EQP00490
      GO TO 1                                                                     EQP00500
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  4   NXY=NXY+1                                                          EQP00510
      DJ=0.                                                              EQP00520
      IF (VDN.EQ.VUP)  GO TO 5                                           EQP00530
      DJ=VDN/(VUP-VDN)                                                   EQP00540
  5   X(NXY)=XMIN+DFLOAT(I-1)*DX0                                        EQP00550
      Y(NXY)=YMIN+DY0*(DFLOAT(JMD-1)-DJ)                                 EQP00560
 10   CONTINUE                                                           EQP00570
      RETURN                                                             EQP00580
      END                                                                EQP00590
C                                                                        PIN00010
C ......................................................................  PIN00020
C                                                                        PIN00030
      FUNCTION PINT (X,Y)                                                PIN00040
C                                                                        PIN00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                                PIN00060
C                                                                        PIN00070
C        JOHN B RETTIG       1/31/79                                     PIN00080
C                                                                        PIN00090
C                                                                        PIN00100
C        PINT INTERPOLATES THE V MATRIX IN BETWEEN THE MESH POINTS       PIN00110
C        USING A 4 POINT LINEAR INTERPOLATION.  IF ANY BOUNDARY IS       PIN00120
C        EXCEEDED, MIRROR IMAGE SYMMETRY IS ASSUMED ABOUT THAT           PIN00130
C        BOUNDARY AND THE INTERPOLATION PERFORMED AS IF THE POINT        PIN00140
C        FELL IN THE MESH.                                               PIN00150
C                                                                        PIN00160
      IMPLICIT REAL*8 (A-H,O-Z)                                          PIN00170
      REAL*8 V(41,401)                                                   PIN00180
      COMMON /A/ V                                                       PIN00190
      COMMON /B/ XMIN,XMAX,DX0,                                          PIN00200
     *           YMIN,YMAX,DY0,                                          PIN00210
     *           M,N,NXY                                                 PIN00220
      XINT=X                                                             PIN00230
      YINT=Y                                                             PIN00240
      IF (X.LT.XMIN)  XINT=2.*XMIN-X                                     PIN00250
      IF (Y.LT.YMIN)  YINT=2.*YMIN-Y                                     PIN00260
      IF (X.GT.XMAX)  XINT=2.*XMAX-X                                     PIN00270
      IF (Y.GT.YMAX)  YINT=2.*YMAX-Y                                     PIN00280
      XO=DFLOAT(M-1)*(XINT-XMIN)/(XMAX-XMIN)                             PIN00290
      YO=DFLOAT(N-1)*(YINT-YMIN)/(YMAX-YMIN)                             PIN00300
      IX=1+IDINT(XO)                                                     PIN00310
      IY=1+IDINT(YO)                                                     PIN00320
      FX=XO-DFLOAT(IX-1)                                                 PIN00330
      FY=YO-DFLOAT(IY-1)                                                 PIN00340
      V0=DABS(V(IX,IY))                                                  PIN00350
      V1=DABS(V(IX+1,IY))                                                PIN00360
      V2=DABS(V(IX,IY+1))                                                PIN00370
      V3=DABS(V(IX+1,IY+1))                                              PIN00380
      DV1=V0+(V1-V0)*FX                                                  PIN00390
      DV2=V2+(V3-V2)*FX                                                  PIN00400
      PINT=DV1+(DV2-DV1)*FY                                              PIN00410
      RETURN                                                             PIN00420
      END                                                                PIN00430
```

Appendix II

RCTGUN III

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C                                                                       GUN00010
C ***********************************************************************GUN00020
C                                                                       GUN00030
C        RECTANGULAR GUN ANALYSIS PACKAGE                               GUN00040
C                                                                       GUN00050
C        JOHN B RETTIG       1/31/79                                    GUN00060
C                                                                       GUN00070
C        MAIN DRIVER ROUTINE, PART III- TRAJECTORY CALCULATIONS         GUN00080
C                                                                       GUN00090
      IMPLICIT REAL*8 (A-H,O-Z)                                         GUN00100
      REAL*8 V(41,401)                                                  GUN00110
      REAL*8 COND(9)                                                    GUN00120
      REAL*8 X(200),Y(200),UX(200),UY(200)                              GUN00130
      INTEGER ICOND(9)                                                  GUN00140
      COMMON /A/ V                                                      GUN00150
      COMMON /B/ XMIN,XMAX,DXO,                                         GUN00160
     *           YMIN,YMAX,DYO,                                         GUN00170
     *           M,N,NXY                                                GUN00180
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        GUN00190
      COMMON /D/ X,Y,UX,UY                                              GUN00200
      COMMON /E/ TITLE1,TITLE2,TITLE3,TITLE4                            GUN00210
      CALL INIT                                                         GUN00220
      READ(8) V                                                         GUN00230
      CALL TRAJ                                                         GUN00240
      STOP                                                              GUN00250
      END                                                               GUN00260
C                                                                       INI00010
C ***********************************************************************INI00020
C                                                                       INI00030
      SUBROUTINE INIT                                                   INI00040
C                                                                       INI00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               INI00060
C                                                                       INI00070
C        JOHN B RETTIG       1/31/79                                    INI00080
C                                                                       INI00090
C                                                                       INI00100
C        DATA INITIALIZATION ROUTINE                                    INI00110
C                                                                       INI00120
      IMPLICIT REAL*8 (A-H,O-Z)                                         INI00130
      REAL*8 V(41,401)                                                  INI00140
      REAL*8 COND(9)                                                    INI00150
      REAL*8 TITLE(4)                                                   INI00160
      INTEGER ICOND(9)                                                  INI00170
      INTEGER NCHAR(9),LINE(120),SPACE                                  INI00180
      DATA NCHAR /1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9/                  INI00190
      DATA SPACE /1H /                                                  INI00200
      COMMON /A/ V                                                      INI00210
      COMMON /B/ XMIN,XMAX,DXO,                                         INI00220
     *           YMIN,YMAX,DYO,                                         INI00230
     *           M,N,NXY                                                INI00240
      COMMON /C/ COND,ICOND,NCOND,CMIN,CMAX,COFF                        INI00250
      COMMON /E/ TITLE                                                  INI00260
      DATA CMINO /1.D4/                                                 INI00270
C                                                                       INI00280
C        DATA DECK SETUP ON LOGICAL RECORD 3  (ALL UNITS MKS)           INI00290
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C                                                                       INI00300
C       CARD    VARIABLE        FORMAT      DESCRIPTION                 INI00310
C                                                                       INI00320
C        1       TITLE(1-2)     2A8      IDENTIFICATION                 INI00330
C                                                                       INI00340
C        2       TITLE(3-4)     2A8      TITLE                          INI00350
C                                                                       INI00360
C        3         M,N          2I5      V MESH SIZE                    INI00370
C                                                                       INI00380
C        4       DXC,DYO        2D12.2   V MESH INCREMENTS (M)          INI00390
C                                                                       INI00400
C       5-13     ICOND,COND   I1,3X,   CONDUCTOR CODES - ICOND IS      INI00410
C                              F6.0     THE CHARACTER USED IN THE MESH INI00420
C                                       TO REPRESENT POTENTIAL COND    INI00430
C                                       (9 OR LESS MAY BE SPECIFIED)   INI00440
C                                                                       INI00450
C       LAST                              (END OF RECORD CARD)          INI00460
C                                                                       INI00470
C                                                                       INI00480
      READ(3,100) (TITLE(I),I=1,4),M,N                                  INI00490
      READ(3,101) DXC,DYO                                               INI00500
C                                                                       INI00510
C       ESTABLISH BOUNDARIES                                            INI00520
C                                                                       INI00530
      XMIN=0.                                                           INI00540
      XMAX=XMIN+DXO*DFLOAT(M-1)                                         INI00550
      YMIN=0.                                                           INI00560
      YMAX=YMIN+DYO*DFLOAT(N-1)                                         INI00570
C                                                                       INI00580
C       WRITE OUT GEOMETRICAL AND INITIAL CONDITION INFORMATION         INI00590
C                                                                       INI00600
      WRITE(1,102)  (TITLE(I),I=1,4),M,N,                               INI00610
     *              XMIN,XMAX,DXO,                                      INI00620
     *              YMIN,YMAX,DYO                                       INI00630
C                                                                       INI00640
C       READ CONDUCTOR CODING AND POTENTIALS                            INI00650
C                                                                       INI00660
      DO 10  I=1,9                                                      INI00670
      NCOND=I                                                           INI00680
      READ(3,103,END=11) ICOND(I),COND(I)                               INI00690
 10   CONTINUE                                                          INI00700
C                                                                       INI00710
 11   NCOND=NCOND-1                                                     INI00720
C                                                                       INI00730
C       CALCULATE MAX, MIN, AND OFFSET                                  INI00740
C                                                                       INI00750
      CMIN=COND(1)                                                      INI00760
      CMAX=COND(1)                                                      INI00770
C                                                                       INI00780
      DO 20  I=1,NCOND                                                  INI00790
      IF (CMIN.GT.COND(I))  CMIN=COND(I)                                INI00800
      IF (CMAX.LT.COND(I))  CMAX=COND(I)                                INI00810
 20   CONTINUE                                                          INI00820
      COFF=CMINO-CMIN                                                   INI00830
      RETURN                                                            INI00840
```

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C                                                                       INI00850
100   FORMAT (2A8/2A8/2I5)                                              INI00860
101   FORMAT (3D12.4)                                                   INI00870
102   FORMAT (/////10X,'IDENT      ',2A8//10X,'TITLE      ',2A8///      INI00880
     *    ' MESH SIZE IS ',I3,' * ',I3,' POINTS'//                     INI00890
     *    ' XMIN = ',D10.4,10X,'XMAX = ',D10.4,10X,'XINC = ',D10.4,    INI00900
     *    ' METERS'//                                                  INI00910
     *    ' YMIN = ',D10.4,10X,'YMAX = ',D10.4,10X,'YINC = ',D10.4,    INI00920
     *    ' METERS'//)                                                 INI00930
103   FORMAT (I1,3X,F6.0)                                               INI00940
      END                                                               INI00950
C                                                                       TRA00010
C .....................................................................  TRA00020
C                                                                       TRA00030
      SUBROUTINE TRAJ                                                   TRA00040
C                                                                       TRA00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               TRA00060
C                                                                       TRA00070
C        JOHN B RETTIG       1/31/79                                    TRA00080
C                                                                       TRA00090
C                                                                       TRA00100
C        THIS PROGRAM FINDS THE TRAJECTORY OF A CHARGED PARTICLE IN     TRA00110
C        THE PRESENCE OF AN ELECTRIC FIELD CREATED BY CONDUCTORS OF     TRA00120
C        VARIOUS POTENTIALS.  THERMAL EFFECTS, RELATIVITY, AND SPACE    TRA00130
C        CHARGE EFFECTS ARE NOT TAKEN INTO ACCOUNT.  FIELD GRADIENTS    TRA00140
C        ARE TAKEN FROM THE POTENTIAL MATRIX V (ASSUMED TO HAVE ALREADY TRA00150
C        BEEN SOLVED BY SOME MEANS).  THEN, A DISCRETIZED FOURTH        TRA00160
C        ORDER DISCRETIZED RUNGE-KUTTA INTEGRATION SCHEME IS USED TO    TRA00170
C        PIECE OUT THE PATH OF THE PARTICLE THROUGH THE MATRIX.         TRA00180
C                                                                       TRA00190
C        IF DESIRED, PARTICLES MAY BE BOUNCED OFF OF BOUNDARIES ABOUT   TRA00200
C        WHICH THE FIELD IS ASSUMED TO BE MIRROR IMAGE SYMMETRICAL.     TRA00210
C                                                                       TRA00220
C                                                                       TRA00230
C                                                                       TRA00240
C        DATA DECK SETUP ON LOGICAL RECORD 5                            TRA00250
C                                                                       TRA00260
C        CARD    VARIABLE    FORMAT      DESCRIPTION                    TRA00270
C                                                                       TRA00280
C          1   X1,Y1,U1,P1   3D12.4,   INITIAL POSITION AND VELOCITY    TRA00290
C                             F12.2     FOR PARTICLE 1 - X1 AND Y1 IN  TRA00300
C                                       METERS, U1 IN METERS/S, P1 IN  TRA00310
C                                       DEGREES FROM +X AXIS           TRA00320
C                                                                       TRA00330
C          2+                           (SAME FOR PARTICLE 2, ETC)     TRA00340
C                                                                       TRA00350
C        LAST                           (END OF RECORD CARD)           TRA00360
C                                                                       TRA00370
C                                                                       TRA00380
      IMPLICIT REAL*8 (A-H,O-Z)                                         TRA00390
      REAL*8 X(200),Y(200),UX(200),UY(200)                              TRA00400
      COMMON /B/ XMIN,XMAX,DX0,                                         TRA00410
     *           YMIN,YMAX,DY0,                                         TRA00420
     *           M,N,NXY                                                TRA00430
      COMMON /C/ CONC,ICOND,NCOND,CMIN,CMAX,COFF                        TRA00440
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      COMMON /D/ X,Y,UX,UY                                              TRA00450
      REAL*8 F(4),Z(4)                                                  TRA00460
      EQUIVALENCE (X1,Z(1)),(Y1,Z(2)),(UX1,Z(3)),(UY1,Z(4))             TRA00470
      INTEGER RUNGE                                                     TRA00480
      DATA TMIN /0./                                                    TRA00490
      DATA DT /2.D-11/                                                  TRA00500
      DATA PI /3.14159265350+0/                                         TRA00510
C                                                                       TRA00520
C        ELECTRON CHARGE/MASS, MKS                                      TRA00530
C                                                                       TRA00540
      DATA ETA /1.7587945D11/                                           TRA00550
      TMAX=TMIN+2.*(YMAX-YMIN)/DSQRT(2.*ETA*(CMAX-CMIN))                TRA00560
C                                                                       TRA00570
      I=0                                                               TRA00580
 10   I=I+1                                                             TRA00590
      READ(5,100,END=30) X1,Y1,U1,P1                                    TRA00600
      RO=(PI/180.)*P1                                                   TRA00610
      UX1=U1*DCOS(RO)                                                   TRA00620
      UY1=U1*DSIN(RO)                                                   TRA00630
      X(I)=X1                                                           TRA00640
      Y(I)=Y1                                                           TRA00650
      UX(I)=UX1                                                         TRA00660
      UY(I)=UY1                                                         TRA00670
      NXY=1                                                             TRA00680
      T=TMIN                                                            TRA00690
C                                                                       TRA00700
C        COMPUTE STEP                                                   TRA00710
C                                                                       TRA00720
 11   K=RUNGE (4,Z,F,T,DT)                                              TRA00730
C                                                                       TRA00740
C        K=1 FLAGS THAT DERIVATIVES ARE NEEDED                          TRA00750
C                                                                       TRA00760
      IF (K.NE.1)  GO TO 12                                             TRA00770
C                                                                       TRA00780
C        COMPUTE GRADIENTS IN POTENTIAL USING CENTRAL DIFFERENCES       TRA00790
C                                                                       TRA00800
      VXH=PINT(X1+.5*DXC,Y1)                                            TRA00810
      VXL=PINT(X1-.5*DXC,Y1)                                            TRA00820
      VYH=PINT(X1,Y1+.5*DYC)                                            TRA00830
      VYL=PINT(X1,Y1-.5*DYC)                                            TRA00840
C                                                                       TRA00850
      GRADVX=(VXH-VXL)/DXC                                              TRA00860
      GRADVY=(VYH-VYL)/DYC                                              TRA00870
C                                                                       TRA00880
C        COMPUTE DERIVATIVES AND CONTINUE RUNGE INTEGRATION             TRA00890
C                                                                       TRA00900
C          - F(1)=DX/DT=UX                                              TRA00910
C          - F(2)=DY/DT=UY                                              TRA00920
C          - F(3)=DUX/DT=ETA*GRADVX                                     TRA00930
C          - F(4)=DUY/DT=ETA*GRADVY                                     TRA00940
C                                                                       TRA00950
      F(1)=UX1                                                          TRA00960
      F(2)=UY1                                                          TRA00970
      F(3)=ETA*GRADVX                                                   TRA00980
      F(4)=ETA*GRADVY                                                   TRA00990
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C                                                                       TRA01000
      GO TO 11                                                          TRA01010
C                                                                       TRA01020
 12   NXY=NXY+1                                                         TRA01030
C                                                                       TRA01040
C        BOUNCE OFF DESIRED BOUNDARIES                                  TRA01050
C                                                                       TRA01060
      IF (X1.GT.XMIN)  GO TO 13                                         TRA01070
      X1 =2.*XMIN-X1                                                    TRA01080
      UX1 =-UX1                                                         TRA01090
 13   CONTINUE                                                          TRA01100
C     IF (Y1.GT.YMIN)  GO TO 14                                         TRA01110
C     Y1=2.*YMIN-Y1                                                     TRA01120
C     UY1=-UY1                                                          TRA01130
C14   CONTINUE                                                          TRA01140
C     IF (X1 .LT.XMAX)  GO TO 15                                        TRA01150
C     X1 =2.*XMAX-X1                                                    TRA01160
C     UX1 =-UX1                                                         TRA01170
C15   CONTINUE                                                          TRA01180
C     IF (Y1.LT.YMAX)  GO TO 16                                         TRA01190
C     Y1=2.*YMAX-Y1                                                     TRA01200
C     UY1=-UY1                                                          TRA01210
C16   CONTINUE                                                          TRA01220
C                                                                       TRA01230
C        RECORD POSITIONS                                               TRA01240
C                                                                       TRA01250
      X(NXY)=X1                                                         TRA01260
      Y(NXY)=Y1                                                         TRA01270
      UX(NXY)=UX1                                                       TRA01280
      UY(NXY)=UY1                                                       TRA01290
C                                                                       TRA01300
C        CHECK LIMITS                                                   TRA01310
C                                                                       TRA01320
      IF (X1.LT.XMIN.OR.X1.GT.XMAX.OR.Y1.LT.YMIN.OR.Y1.GT.YMAX          TRA01330
     *          .OR.T.GT.TMAX.OR.NXY.EQ.200)  GO TO 20                  TRA01340
      GO TO 11                                                          TRA01350
C                                                                       TRA01360
C        PRINT AND PLOT INFORMATION                                     TRA01370
C                                                                       TRA01380
 20   WRITE(1,101) I                                                    TRA01390
      DO 21  K=1,NXY                                                    TRA01400
      T=TMIN+DFLOAT(K-1)*DT                                             TRA01410
      U=DSQRT(UX(K)*UX(K)+UY(K)*UY(K))                                  TRA01420
      ANG=(180./PI)*DATAN2(UY(K),UX(K))                                 TRA01430
      WRITE(1,102)  T,X(K),Y(K),U,ANG                                   TRA01440
 21   CONTINUE                                                          TRA01450
      CALL TJPLOT                                                       TRA01460
      GO TO 10                                                          TRA01470
 30   CALL POFF                                                         TRA01480
      RETURN                                                            TRA01490
C                                                                       TRA01500
100   FORMAT (3D12.4,F12.2)                                             TRA01510
101   FORMAT (/////10X,' ***** PARTICLE ',I2,' *****'//                 TRA01520
     *    6X,'T(S)',8X,'X(M)',8X,'Y(M)',8X,'U(M/S)',6X,'ANGLE')         TRA01530
102   FORMAT (1X,4D12.3,F10.2)                                          TRA01540
```

```
      END                                                                TRA01550
C                                                                        RUN00010
C ..................................................................     RUN00020
C                                                                        RUN00030
      FUNCTION RUNGE (N,Y,F,X,H)                                         RUN00040
C                                                                        RUN00050
C        RECTANGULAR CUN ANALYSIS PACKAGE                                RUN00060
C                                                                        RUN00070
C        JOHN B RETTIG       1/31/79                                     RUN00080
C                                                                        RUN00090
C                                                                        RUN00100
C        FOURTH ORDER RUNGE-KUTTA INTEGRATION                            RUN00110
C                                                                        RUN00120
C        COPIED FROM CARNAHAN, LUTHER, & WILKES, 'APPLIED NUMERICAL      RUN00130
C        METHODS', NEW YORK, WILEY, 1969, PP 374-5.                      RUN00140
C                                                                        RUN00150
      IMPLICIT REAL*8 (A-H,O-Z)                                          RUN00160
      INTEGER RUNGE                                                      RUN00170
      REAL*8 PHI(4),SAVEY(4),Y(N),F(N)                                   RUN00180
      DATA M/0/                                                          RUN00190
C                                                                        RUN00200
      M=M+1                                                              RUN00210
      GO TO (1,2,3,4,5),M                                                RUN00220
C                                                                        RUN00230
C     ....PASS 1....                                                     RUN00240
   1  RUNGE=1                                                            RUN00250
      RETURN                                                             RUN00260
C                                                                        RUN00270
C     ....PASS 2....                                                     RUN00280
   2  DO 22  J=1,N                                                       RUN00290
      SAVEY(J)=Y(J)                                                      RUN00300
      PHI(J)=F(J)                                                        RUN00310
  22  Y(J)=SAVEY(J)+0.5*H*F(J)                                           RUN00320
      X=X+0.5*H                                                          RUN00330
      RUNGE=1                                                            RUN00340
      RETURN                                                             RUN00350
C                                                                        RUN00360
C     ....PASS 3....                                                     RUN00370
   3  DO 33  J=1,N                                                       RUN00380
      PHI(J)=PHI(J)+2.0*F(J)                                             RUN00390
  33  Y(J)=SAVEY(J)+0.5*H*F(J)                                           RUN00400
      RUNGE=1                                                            RUN00410
      RETURN                                                             RUN00420
C                                                                        RUN00430
C     ....PASS 4....                                                     RUN00440
   4  DO 44  J=1,N                                                       RUN00450
      PHI(J)=PHI(J)+2.0*F(J)                                             RUN00460
  44  Y(J)=SAVEY(J)+H*F(J)                                               RUN00470
      X=X+0.5*H                                                          RUN00480
      RUNGE=1                                                            RUN00490
      RETURN                                                             RUN00500
C                                                                        RUN00510
C     ....PASS 5....                                                     RUN00520
   5  DO 55  J=1,N                                                       RUN00530
  55  Y(J)=SAVEY(J)+(PHI(J)+F(J))*H/6.0                                  RUN00540
```

```
      M=0                                                               RUN00550
      RUNGE=0                                                           RUN00560
      RETURN                                                            RUN00570
C                                                                       RUN00580
      END                                                               RUN00590
C                                                                       PIN00010
C ..................................................................    PIN00020
C                                                                       PIN00030
      FUNCTION PINT (X,Y)                                               PIN00040
C                                                                       PIN00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               PIN00060
C                                                                       PIN00070
C        JOHN B RETTIG       1/31/79                                    PIN00080
C                                                                       PIN00090
C                                                                       PIN00100
C        PINT INTERPOLATES THE V MATRIX IN BETWEEN THE MESH POINTS      PIN00110
C        USING A 4 POINT LINEAR INTERPOLATION.  IF ANY BOUNDARY IS      PIN00120
C        EXCEEDED, MIRROR IMAGE SYMMETRY IS ASSUMED ABOUT THAT          PIN00130
C        BOUNDARY AND THE INTERPOLATION PERFORMED AS IF THE POINT       PIN00140
C        FELL IN THE MESH.                                              PIN00150
C                                                                       PIN00160
      IMPLICIT REAL*8 (A-H,O-Z)                                         PIN00170
      REAL*8 V(41,401)                                                  PIN00180
      COMMON /A/ V                                                      PIN00190
      COMMON /B/ XMIN,XMAX,DXO,                                         PIN00200
     *           YMIN,YMAX,DYO,                                         PIN00210
     *           M,N,NXY                                                PIN00220
      XINT=X                                                            PIN00230
      YINT=Y                                                            PIN00240
      IF (X.LT.XMIN)  XINT=2.*XMIN-X                                    PIN00250
      IF (Y.LT.YMIN)  YINT=2.*YMIN-Y                                    PIN00260
      IF (X.GT.XMAX)  XINT=2.*XMAX-X                                    PIN00270
      IF (Y.GT.YMAX)  YINT=2.*YMAX-Y                                    PIN00280
      XO=DFLOAT(M-1)*(XINT-XMIN)/(XMAX-XMIN)                            PIN00290
      YO=DFLOAT(N-1)*(YINT-YMIN)/(YMAX-YMIN)                            PIN00300
      IX=1+IDINT(XO)                                                    PIN00310
      IY=1+IDINT(YO)                                                    PIN00320
      FX=XO-DFLOAT(IX-1)                                                PIN00330
      FY=YO-DFLOAT(IY-1)                                                PIN00340
      V0=DABS(V(IX,IY))                                                 PIN00350
      V1=DABS(V(IX+1,IY))                                               PIN00360
      V2=DABS(V(IX,IY+1))                                               PIN00370
      V3=DABS(V(IX+1,IY+1))                                             PIN00380
      DV1=V0+(V1-V0)*FX                                                 PIN00390
      DV2=V2+(V3-V2)*FX                                                 PIN00400
      PINT=DV1+(DV2-DV1)*FY                                             PIN00410
      RETURN                                                            PIN00420
      END                                                               PIN00430
C                                                                       TJP00010
C ..................................................................    TJP00020
C                                                                       TJP00030
      SUBROUTINE TJPLOT                                                 TJP00040
C                                                                       TJP00050
C        RECTANGULAR GUN ANALYSIS PACKAGE                               TJP00060
C                                                                       TJP00070
```

```
C         JOHN B RETTIG       1/31/79                                    TJP00080
C                                                                        TJP00090
C                                                                        TJP00100
C         TRAJECTORY PLOT SETUP FOR THE ZETA PLOTTER                     TJP00110
C                                                                        TJP00120
      REAL*8 V(41,401)                                                   TJP00130
      REAL*8 X(200),Y(200),UX(200),UY(200)                               TJP00140
      REAL*8 XMIN,XMAX,DXO,YMIN,YMAX,DYO,TMIN,TMAX,DT                    TJP00150
      COMPLEX*16 IDENT,TITLE                                             TJP00160
      COMMON /A/ V                                                       TJP00170
      COMMON /B/ XMIN,XMAX,DXO,                                          TJP00180
     *           YMIN,YMAX,DYO,                                          TJP00190
     *           M,N,NXY                                                 TJP00200
      COMMON /D/ X,Y,UX,UY                                               TJP00210
      COMMON /E/ IDENT,TITLE                                             TJP00220
      DATA WIDTH /4./                                                    TJP00230
      DATA IFLAG /0/                                                     TJP00240
C                                                                        TJP00250
C         FIRST TIME THROUGH?                                            TJP00260
C                                                                        TJP00270
      IF (IFLAG.NE.0)  GO TO 50                                          TJP00280
      IFLAG=1                                                            TJP00290
      CALL PLOTF (10,2)                                                  TJP00300
      CALL FACTOR (2.)                                                   TJP00310
C                                                                        TJP00320
C         DEFINE SCALES                                                  TJP00330
C                                                                        TJP00340
      XL=WIDTH                                                           TJP00350
      YL=WIDTH*SNGL((YMAX-YMIN)/(XMAX-XMIN))                             TJP00360
      DX=SNGL(XMAX-XMIN)/XL                                              TJP00370
      DY=SNGL(YMAX-YMIN)/YL                                              TJP00380
      XO=SNGL(XMIN)                                                      TJP00390
      YO=SNGL(YMIN)                                                      TJP00400
C                                                                        TJP00410
C         TITLE                                                          TJP00420
C                                                                        TJP00430
      CALL SYMBOL (YL/3.,XL+1.,.15,IDENT,0.,16)                          TJP00440
      CALL SYMBOL (YL/3.,XL+.50,.15,TITLE,0.,16)                         TJP00450
C                                                                        TJP00460
C         SCALE ALL FUTURE PLOTTING TO GUN DIMENSIONS                    TJP00470
C                                                                        TJP00480
      CALL OFFSET (YO,DY,XO,DX)                                          TJP00490
C                                                                        TJP00500
C         DRAW CONDUCTORS                                                TJP00510
C                                                                        TJP00520
      DO 20  I=1,M                                                       TJP00530
      XO=SNGL(DXO)*FLOAT(I-1)                                            TJP00540
      JTEST=0                                                            TJP00550
      DO 10  J=1,N                                                       TJP00560
      IF (V(I,J).LT.0..AND.JTEST.EQ.0)  GO TO 11                         TJP00570
      IF (V(I,J).GT.0..AND.JTEST.EQ.1)  GO TO 12                         TJP00580
      IF (J.EQ.N.AND.JTEST.EQ.1)  GO TO 12                               TJP00590
      GO TO 10                                                           TJP00600
 11   JTEST=1                                                            TJP00610
      JSTART=J                                                           TJP00620
```

```
      GO TO 10                                                          TJP00630
 12   JTEST=0                                                           TJP00640
      JSTOP=J-1                                                         TJP00650
      IF (J.EQ.N)  JSTOP=J                                              TJP00660
      IF(JSTART.EQ.JSTOP)  GO TO 10                                     TJP00670
      YO=SNGL(DYO)*FLOAT(JSTART-1)                                      TJP00680
      CALL PLOTX (YO,XO,13)                                             TJP00690
      YO=SNGL(DYO)*FLOAT(JSTOP-1)                                       TJP00700
      CALL PLOTX (YO,XO,12)                                             TJP00710
 10   CONTINUE                                                          TJP00720
 20   CONTINUE                                                          TJP00730
C                                                                       TJP00740
      DO 40  J=1,N                                                      TJP00750
      YO=SNGL(DYO)*FLOAT(J-1)                                           TJP00760
      ITEST=0                                                           TJP00770
      DO 30  I=1,M                                                      TJP00780
      IF (V(I,J).LT.0..AND.ITEST.EQ.0)  GO TO 31                        TJP00790
      IF (V(I,J).GT.0..AND.ITEST.EQ.1)  GO TO 32                        TJP00800
      IF (I.EQ.M.AND.ITEST.EQ.1)  GO TO 32                              TJP00810
      GO TO 30                                                          TJP00820
 31   ITEST=1                                                           TJP00830
      ISTART=I                                                          TJP00840
      GO TO 30                                                          TJP00850
 32   ITEST=0                                                           TJP00860
      ISTOP=I-1                                                         TJP00870
      IF (I.EQ.M)  ISTOP=I                                              TJP00880
      IF(ISTART.EQ.ISTOP)  GO TO 30                                     TJP00890
      XO=SNGL(DXO)*FLOAT(ISTART-1)                                      TJP00900
      CALL PLOTX (YO,XO,13)                                             TJP00910
      XO=SNGL(DXO)*FLOAT(ISTOP-1)                                       TJP00920
      CALL PLOTX (YO,XO,12)                                             TJP00930
 30   CONTINUE                                                          TJP00940
 40   CONTINUE                                                          TJP00950
 50   CALL LINE (Y,X,NXY,2,0,12)                                        TJP00960
      RETURN                                                            TJP00970
C                                                                       TJP00980
      END                                                               TJP00990
```

Appendix III

BEAMSPREAD

```
 gular  *"
1: prt "*  Beams
 pread  *";spc 2
2: dim Q$[1],
 R[3],A$[3,20]
3: 1.758e11→N;
 8.856e-12→E;
 flt 3
4: cfg 13;enp
 "Number of disc
 rete intervals?
 ";M;if flg13;
 jmp 0
5: dim J[2,M],
 Y[0:M]
6: cfg 13;enp
 "Spacing of
 intervals (M)?"
 ,S;if flg13;
 jmp 0
7: dsp "Enter
 initial current
  densities";
 wait 2000
8: for I=1 to M
9: enp J[1,I];
 next I
10: ""→Q$;ent
 "Want profile
 plot(Y/N)?";Q$
11: cfg 0;if
 cap(Q$)="Y";
 sfg 0;0→R[1];
 9→R[2];12→R[3];
 trk 0;ldf 10
12: if not flg0;
 gto "Drift"
13: plt 0,0,1
14: for I=1 to M
15: plt S(I-1),
 J[1,I],2
19: flt 3
20: "Drift":
21: cfg 13;enp
 "Acceleration
 potential (kV)?
 ",V;if flg13;
 jmp 0
22: cfg 13;enp
 "Drift space
 (M)?",D;if flg1
 3;jmp 0
23: 0→K→Y[0];
 (1000V)↑(-3/
 2)ΠD/4E↑(2N)→C
24: for I=1 to
 M;K+SJ[1,I]→K
25: IS+CK→Y[I];
 J[1,I](S/(Y[I]-
 Y[I-1]))→J[2,I]
26: spc ;prt "Y
 = ",Y[I],"J =
 ",J[2,I]
27: next I;spc
28: prt "K = ",
 K," A/M";spc 3
29: if not flg0;
 gto "Drift"
30: plt 0,0,1
31: for I=1 to M
32: plt Y[I-1],
 J[2,I],2
33: plt Y[I],
 J[2,I],2
34: next I
35: plt Y[M],0,
 2;pen
36: gto "Drift"
37: end
```

Appendix IV

CONVOLVE

```
 Beam      * ,"
 Convolution  *
 "¡spc 2
1: dim M[2]¡dim
 G[-16:16]¡dim
 Y[65]¡dim N[3]¡
 rad
2: enp "Diode
 spacing?",S;
 "Diode width?",
 W
3: enp "No. beam
  points?",Q;
 "Increment betw
 een points?",D
4: enp "Start
 beam drive?",
 N[1],"End beam
 drive?",N[3];
 "Increment?",
 N[2]
5: enp "Pos.
 sens.?",M[1];
 "Neg. sens.?",
 M[2],"Data sour
 ce?",r2
6: if r2#0¡enp
 "File?",r9¡jmp
 3
7: enp "Beam
 type?",r16
8: if r16¡enp
 "Truncation?",
 r17
9: enp "Highest
 harmonic?",C;
 "Plot?",r8,"Sat
 uration drop?",
 r12
10: if r8=1¡sfg
 1
... .. C=0:1→N:
```

```
 _ ...
14: if r8=2¡sfg
 3
15: dim F[-Q:Q]
16: if N[2]=0¡
 jmp 3
17: (N[3]-N[1])/
 N[2]→r5
18: dim P[2,0:r5
 +1]
19: W+S→L
20: "Beam":cll
 'Generate'(Q)
21: cll 'Zero'
22: enp "DC Tran
 sfer?",r1
23: if r1¡cll
 'DC'
24: fmt 2,f6.2,
 2x,e8.2
25: spc ¡flt 4¡
 prt "Beam profi
 le"¡spc
26: for I=-Q to
 Q¡wrt 16.2,ID,
 F[I]¡next I
27: N[1]→r3¡0→r1
28: "Response":s
 pc
29: cll 'Convolv
 e'
30: cll 'Fourier
 '(C)
31: cll 'Efficie
 ncy'
32: if N[2]=0¡
 sto "Quit"
33: (r3-N[1])/
 N[2]→r4
34: r3↑2→P[1,r4]
```

```
 "Response"
37: max(F[*])→r1
 3;0→I
38: if F[I]>=.5r
 13;jmp 2
39: I-1>0→I;jmp
 -1
40: min(S+ID,S-
 ID+W)→r3
41: cll 'Convolv
 e'
42: cll 'Fourier
 '
43: A[1]↑2→P[2,
 r5+1]
44: dsp "Transfe
 r plot"
45: stp
46: scl -20,10,-
 20,10
47: axe 0,0,2,2;
 sfg 14
48: for I=0 to
 r5;10log(P[1,
 I]/r3↑2)→X;10lo
 g(P[2,I]/P[2,
 r5+1])→Y
49: prt "Pin",X,
 "Pout",Y;spc
50: if X<-20;-
 20→X
51: if Y<-20;-
 20→Y
52: plt X,Y
53: next I
54: pen;plt -20,
 -20;pen
55: "Quit":prt
 "**************
 **";spc 3;end
56: "Generate":i
 mps
58: if r16;jmp 3
59: for I=-p1
 to p1;i→F[I]
60: next I;jmp 6
61: for I=-p1
 to p1;if (exp(-
 6.9I↑2/Q↑2)→F[I
 ])>r17;r17→F[I]
62: next I;jmp 4
63: "Data":for
 I=-p1 to p1;
 ent F[I]
64: next I
65: trk 1;rcf
 r9,F[*];trk 0
66: ret
67: "Tape":trk
 1;ldf r9,F[*];
 trk 0
68: ret
69: "Fourier":π/
 32→p2
70: gsb "Foure"
71: if p1=0;sto
 "Finish"
72: prt "Fourier
  Current Harmon
 ics (dB)";spc
73: fmt 0,f1,0,
 f8.2
74: if (abs(A[0]
 /A[1])→r7)>1e-
 10;wrt 16,"A[",
 0,"] = ",20log(
 r7)
75: for I=1 to N
76: if (abs(A[I]
 /A[1])→r7)>1e-
 10;wrt 16,"A[",
```

```
 10;prt 16;"B[";
 I;"] = ";20log(
 r7)
78: spc 1;next I
79: "Finish":ret

80: "Foure":rad;
 cfg 2;1→J;0→I;
 2π→p3
81: if (I+1→I)>6
 5;gto +8
82: -π+(I-1)p2→X
 ;Y[I]→Y;if I=1
 or I=65;1→M;
 gto +3
83: if M=4;2→M;
 gto +2
84: 4→M
85: cos(2πX/p3→E
 )→p4→F;sin(E)→p
 5→G
86: MYF+A[J]→A[J
 ];MYG+B[J]→B[J]
87: if (J+1→J)<=
 N;p4F-p5G→T;
 p5F+p4G→G;T→F;
 gto -1
88: 1→J;gto -7
89: Y[1]+4Y[2]+
 Y[65]→p4;3→I
90: p4+2Y[I]+
 4Y[I+1]→p4;jmp
 (I+2→I)>=65
91: p4p2/3p3→A[0
 ];1→J
92: 2A[J]p2/3p3→
 A[J];2B[J]p2/
 3p3→B[J];jmp
 (J+1→J)>N
93: end

 )→r10
96: next I
97: if r10=0;
 0→r11;jmp 2
98: 32A[1]r12/
 r10→r11
99: fxd 2;prt
 "Displ = ";r3
100: fxd 4;prt
 "Effic = ";r11
101: spc 1;ret
102: "Convolve":
 for I=-16 to 1
103: 0→G[I]
104: r3sin(Iπ/
 32)→P
105: for J=-Q
 to Q
106: if abs(P+
 JD)>L;0→H;gto
 "Sum"
107: if abs(P+
 JD)<S;0→H;gto
 "Sum"
108: if P+JD<=-
 S;-M[2]→H;gto
 "Sum"
109: if P+JD>=S;
 M[1]→H
110: "Sum":F[J]H
 D+G[I]→G[I]
111: next J
112: next I
113: max(G[*])→Z
114: for I=-16
 to 16;G[I]→Y[I+
 17]
115: next I
116: for I=15
 to -16 by -1;
```

```
 9π/4,-1.2,1.2
120: if flg1;
 jmp 3
121: axe 0,0,π/
 4,.2
122: sfg 1
123: for K=1 to
 65
124: plt (K-1)π/
 32,Y[K]/Z
125: next K
126: pen
127: "Done":ret
128: "DC":enp
 "No. of transfe
 r points",p1
129: 1.5(W+S)/
 p1→p2
130: for I=1 to
 p1;Ip2→P
131: 0→p3
132: for J=-Q
 to Q
133: if abs(P+
 JD)<S;0→H;gto
 "Add"
134: if abs(P+
 JD)>L;0→H;gto
 "Add"
135: if P+JD<=-
 S;-M[2]→H;gto
 "Add"
136: if P+JD>=S;
 M[1]→H
137: "Add":F[J]H
 D+p3→p3
138: next J
139: prt "Drive"
 ,Ip2;"Current",
 p3*...
```

```
 ,0 "
144: if abs(JD)<
 S;0→H;gto "Tota
 l"
145: if abs(JD)>
 L;0→H;gto "Tota
 l"
146: if JD<=-S;
 M[2]→H;gto "Tot
 al"
147: if JD>=S;
 M[1]→H
148: "Total":F[J
 ]HD+r6→r6
149: next I
```

Appendix IV

KEY PERSONNEL

DOUGLAS B. CLARK, Member of the Technical Staff, Tube Division, Devices Group. Born December 31, 1946, Oakland, California. Nine years experience. B.S., Electrical Engineering, University of California at Berkeley, 1969. Graduate studies in Electrical Engineering at Loyola University of Los Angeles.

Mr. Clark is currently a Project Engineer with the Electron Bombarded Semiconductors Group. He is responsible for design and development of state-of-the-art EBS devices.

From February 1974 to May 1977, Mr. Clark was with the Solid State West Division of Varian Associates in Palo Alto, California. He was Project Engineer on a variety of development and production projects involving Gun diode amplifiers, YIG-tuned Gunn Oscillators, and bipolar transistor amplifiers.

From June 1969 to February 1974, Mr. Clark was with the Hughes Aircraft Company, Electron Dynamics Division, where he was a Member of the Technical Staff. His responsibilities included that of Project Engineer on state-of-the-art, dual mode, multi-octave traveling-wave tubes. He also was responsible for production of high pulse power space tubes.

JOHN B. RETTIG, Member of the Technical Staff, Tube Division. Born January 8, 1954, Toledo, Ohio. B.S.E.E., 1977, M.S.E.E., 1978, Purdue University.

Mr. Rettig is presently working on the development of an EBS space amplifier for NASA Goddard Research Center that must meet stringent linearity and efficiency specifications.

Formerly he was a research assistant at Purdue University, engaged in High Gradient Magnetic Separation studies. This involved experimental quantization of 3-dimensional buildups of small paramagnetic particles on saturated ferromagnetic wires.

Mr. Rettig is a member of Tau Beta Pi and IEEE.